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Mahesh K. Gaur *Editors*

Food Security and Land Use Change under Conditions of Climatic Variability

A Multidimensional Perspective

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Editors' Preface

Food security covers aspects at all spatial levels from local to global and from an interdisciplinary and systemic food systems perspective. This book aims to better understand environmental, nutritional, agricultural, demographic, socioeconomic, political, technological, and institutional drivers, costs, and outcomes of current and future food security. Interactions with contextual factors include climate change, urbanization, greening the economy, and data-driven technologies. Agriculture began some 12,000 years ago. Since that time, approximately 7000 plant species and several thousand animal species have been used for human food. Today, however, the worldwide trend is toward changing food habits and dietary simplification (Fig. 1), with consequent negative impacts on food and nutrition security (Emadi and Rahmanian, this volume and Burlingame et al. 2012; Boye and Arcand 2012).

Agricultural landscapes also suffer from *genetic erosion* as traditional landraces and "minor crops" are rapidly disappearing, replaced by modern varieties.[1] Such genetic erosion means that future options for domestication, breeding, and evolution could be irreversibly lost, a fact that is being recognized through the development of "red list" for cultivated species. Agrobiodiversity is the subset of biological diversity important to food and agriculture. It is the human element that sets agrobiodiversity apart from "wild" biodiversity. Agrobiodiversity is the outcome of the interactions among genetic resources, the environment, and farmers' management systems and practices.

[1] The food composition indicator relates to the nutrients and bioactive non-nutrients that are provided by biodiversity.

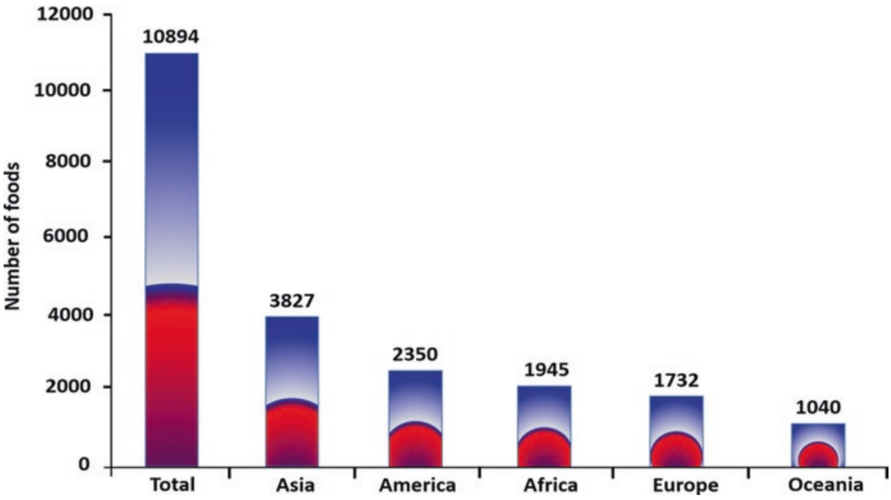

Fig. 1 The number of foods reported for the food composition indicator in 2010 (Source: Burlingame et al. 2012)

Urbanization and infrastructure development also lead to land-use change often in areas where high agrobiodiversity is found. Shifts in land use also need to be considered. The consumption of meat tends to increase as people get richer, which raises the demand for feed. In addition, in some areas, biofuel production has reduced land available for crop cultivation. Urbanization and infrastructure development convert significant agricultural areas – often areas of high soil fertility – to nonagricultural uses. Meeting the world's demands for more and better food and feed while sustaining ecosystem services will be critical. With few remaining opportunities for expanding global agricultural areas, these needs will have to be met largely through agricultural intensification that builds on sustainable management of agrobiodiversity.

The rate of loss of genetic resources is projected to increase as the world gets hotter, a process that will affect agrobiodiversity. Climate change will speed up these processes. The "area suitability" of species will change with the climate, and marginal populations will be threatened with extinction unless they can migrate or adapt quickly enough. Loss of genetic diversity will, in turn, reduce the options for adaptation to climate change. Agrobiodiversity holds the key to adapting to climate change through the movement of germplasm or the breeding of new varieties that can withstand drought stress or flooding or that can resist new pests and diseases.

The food systems of indigenous peoples show the important role that a diversified diet, based on local plant and animal species and traditional foods, can play to support health and well-being. By contrast, increasing the consumption of processed and commercial foods over time will have a negative impact on the quality of the diet. Countries, communities, and cultures that maintain traditional food systems are better able to conserve and access local food specialties based on a corresponding diversity of crops and animal breeds. As a result, they will be less likely to fall prey to diet-related diseases (FAO, 2011, Willett and Rockstrom 2019).

There are a number of important "issues" that are discussed in this book. We seek to address these topics, either in specific chapters or across the spectrum of the whole book all set against the impact of climate variability. Some contributions are on cross-cutting topics, addressing availability, access, and utilization in an integrated way. We include case studies from rural Africa and South Asia (Bangladesh, India, China, Indonesia) and from urbanized centers too. The nexus between water, soil, food, and population is explored and discussed. Climate change affects livestock production in multiple ways, both directly and indirectly. The most important impacts are on animal productivity, animal health, and biodiversity – all of which affect directly the livelihoods of over 200 million people.

The alarming pace of biodiversity loss and ecosystem degradation and its negative impact on poverty and health make a compelling case for reexamining food systems. Currently, close to one billion people suffer from hunger and another two billion from micronutrient deficiencies. Diets that are low in variety but high in energy contribute to the escalating problems of obesity and chronic diseases that particularly threaten poor people in developing countries. In recent years, reduced access to land and natural resources, environmental degradation, climate change, globalization, and the westernization of diet and lifestyle have dramatically affected the role that traditional foods play in the lives of small farmers and indigenous societies. Studies have linked these changes to a wide range of negative consequences, including food insecurity, poor health, nutrition deficiencies, ecosystem deterioration, and cultural erosion. The consequences of the shift in production and consumption patterns are significant.

Human-environment interactions are extremely complex and can be obscured not only by the dynamic complexity of the climate system but also by the diversity in societal response and human adaptation to changing landscapes (Adger et al. 2013). Some shifts in landscapes are brought on by changing climate or by land-use change caused by more variable and less reliable precipitation patterns. Societal response to climate variability and change (higher temperatures, seasonal precipitation patterns) varies greatly and relies on a particular level of cultural sophistication and economic development than can seldom be measured. The overall health of the population, agricultural practices, market conditions, and environmental stability in any given country all contribute to this complexity. Among the overarching principles are (i) the recognition that the health of human beings cannot be isolated from the health of ecosystems and (ii) the affirmation of the need for all-inclusive cooperation in activities to improve human and environmental health through sustainable diets.

More than 30% of the world was hungry in the 1960s; today, it is around 15%. The huge success of feeding an extra three billion people ranks as one of humanity's greatest feats. Agricultural science underpinned those successes through a wealth of innovative research for development conducted in diverse environments and cultures around the world. Now, 50 years on, a new generation of agricultural scientists and thought leaders is needed to carry on this scientific and humanitarian work. We believe that this book will stimulate and inspire.

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About the Editors

Victor R. Squires is an Australian. He is both Former Dean of the Faculty of Natural Resources and Former Professor in the University of Adelaide and is an internationally recognized Dryland Management Expert. He has completed his *B.A. Litt. B. and M.A. (Hons)* at the University of New England and his Ph.D. at Utah State University, USA. He has a background in teaching and applied researching and holds a Ph.D. in Natural Resources Management and Range Ecology, master's degree in Ecology and Botany, and bachelor's degree in Botany and Geography. As an Educator, he taught graduate and postgraduate students in Australia and conducted applied research and training programs for institutions and government agencies over the world. He has worked in many developing countries, e.g., China, Mongolia, East Africa, and Central Asia.

He is Author/Editor of 18 books and more than 150 papers. His recent books include *Climate Variability Impacts on Land Use and Livelihoods in Drylands* (Springer 2018), *Carbon Management for Promoting Local Livelihood in the Hindu Kush Himalayan (HKH) Region* (Springer 2020), *Grasslands of the World: Diversity, Management and Conservation* (CRC Press 2018), *Desertification: Past, Current and Future Trends* (NOVA 2018), and *Drylands: Biodiversity, Conservation and Management* (NOVA 2019).

He has been recognized by the State Council in China and awarded gold medals for International Science and Technology Cooperation (2008) and a Friendship (YouYi) Award (2011) and an Outstanding Achievement Award from the Society for Range Management, USA.

Mahesh K. Gaur is working as Senior Scientist at ICAR-Central Arid Zone Research Institute, Jodhpur, India, since September 2012. He specializes in arid land geography and application of satellite remote sensing, GIS, and digital image processing for natural resource mapping, management, and assessment, drought, desertification, and land degradation. He has worked as Associate Professor for more than 13 years in the Department of Higher Education, Government of Rajasthan State, India, where he taught graduate and postgraduate students. He has conducted various sponsored studies of ISRO, SAC, UGC, various Ministries of the Government of India, ICARDA, etc. He has published 6 books and has contributed more than 60 research papers and 30 book chapters that have appeared in national and international publications. His recent books include *Climate Variability Impacts on Land Use and Livelihoods in Drylands* (Springer 2018), *Climate Change and Agroforestry: Adaptation, Mitigation and Livelihood Security* (NIPA 2018), and *Drylands: Biodiversity, Conservation and Management* (NOVA 2019).

He is associated with *Global Geography Education*, Association of American Geographers, USA; *RIGEO*, Turkey (Associate Editor); *Journal of Arid Environments*, the Netherlands; Society for Conservation Biology, Arlington, USA; Scientific Board of International *Journal of Ecosystem and Ecography* (Member), USA; etc. He was awarded prestigious associateships by the UGC of India and Scientific Assembly of the International Committee on Space Research (COSPAR). He has been awarded *Government Citizen Karamveer Award* 2011 by iCONGO for working in the field of Higher Education and Environment and Technology Applications for Community Upliftment and Millennium Award for working in the field of Environment. He has been to South Africa, Namibia, and Costa Rica on academic assignments. He is Member of a number of national and international scientific organizations and editorial boards of journals and of the Government of India constituted task force on preparation of mountain zone regulations and policies and is Secretary of the INCA, Jodhpur Chapter.

Part I
Food Security as a Global Issue

The four chapters in this *part* raise and discuss issues that resonate at global level. Foremost among them is the importance of time. Many issues that affect food security have a sudden and immediate impact, while others, like climate change, are "slow-onset" phenomena. The effects may be already perceptible but are likely to gather momentum as time goes by. To begin, *Jafari & Jafari* deal with the vocabulary around food security and elaborate on definitions and meanings. *Emadi and Bahmanian* make a wide-ranging commentary on the history of thinking about food production and food security, hunger and famine, and the evolution of policy and efforts to operationalize and mainstream food security into national plans. The challenge is to find ways to embrace a food systems approach. To avert hunger and famine, there has been much effort to increase food production, but mismanagement can lead to land degradation and land abandonment. *Squires and Gaur* take up the task of explaining agricultural land quality and the importance of maintaining or even improving land quality and explore the issues related to maintenance of productivity in the face of climate variability and the increasing anthropogenic pressure on agricultural land, in particular. Water is a production factor that is vital and which is already in short supply. *Nagabhatla* et al. examine the links between water and food security with special reference to migration to (or away from) areas where the water regime suits their production technology.

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-

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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).

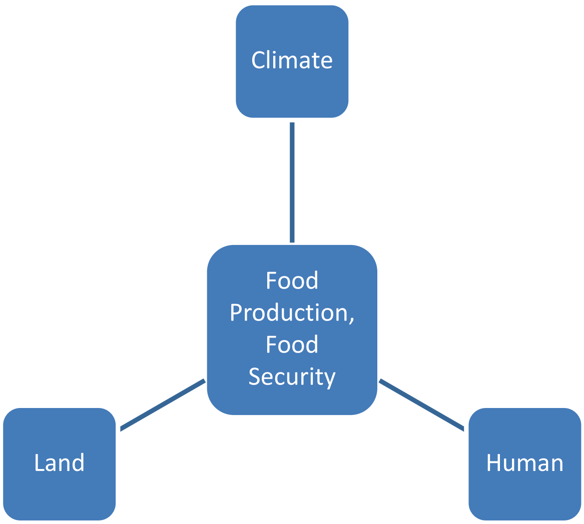

Fig. 1.1 Principal factors affecting food security

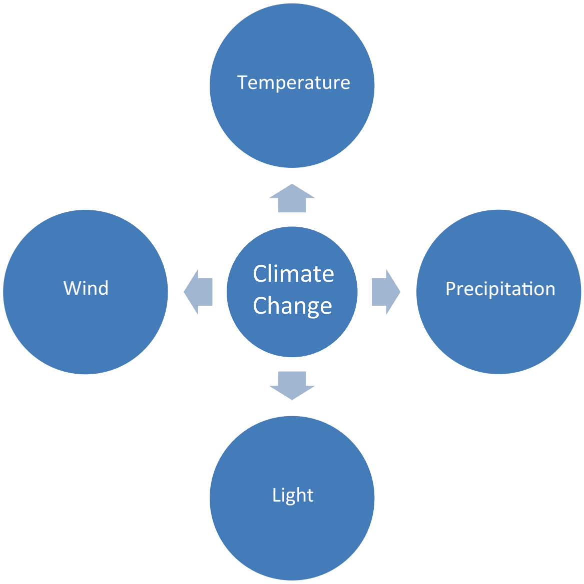

Fig. 1.2 Main climate-related factors affecting food production

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.

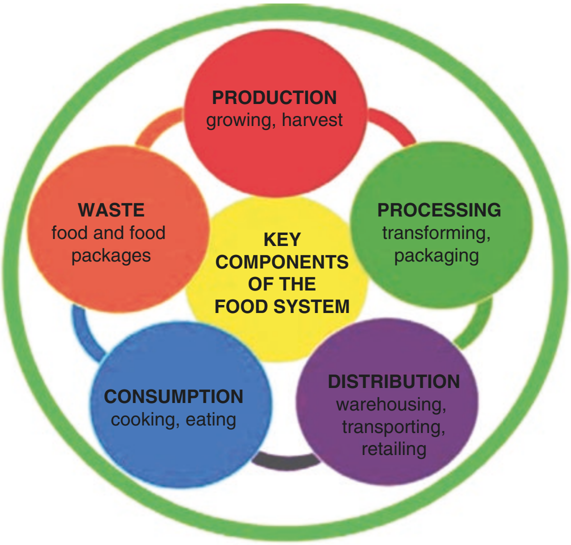

Fig. 1.3 Key components of the food system (K. State 2019)

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).

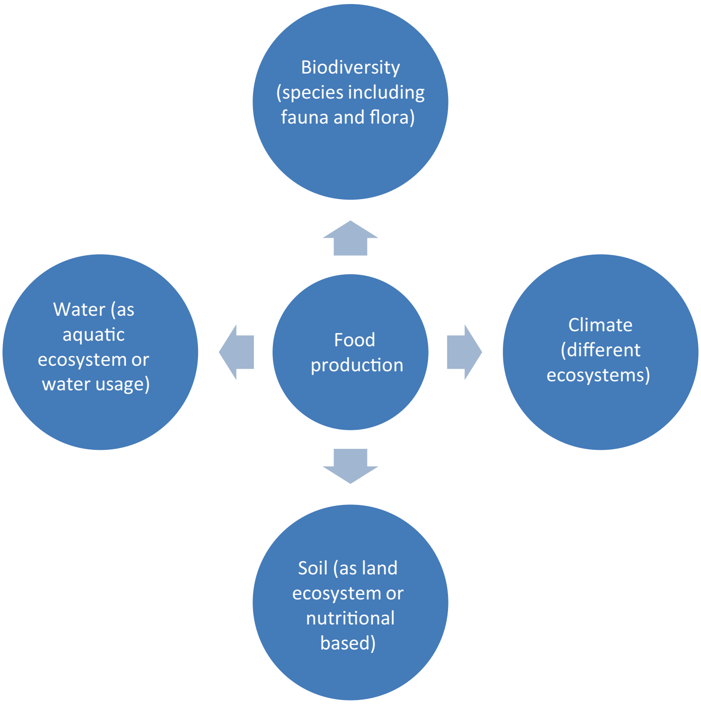

Fig. 1.4 Main factors related to food production

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.

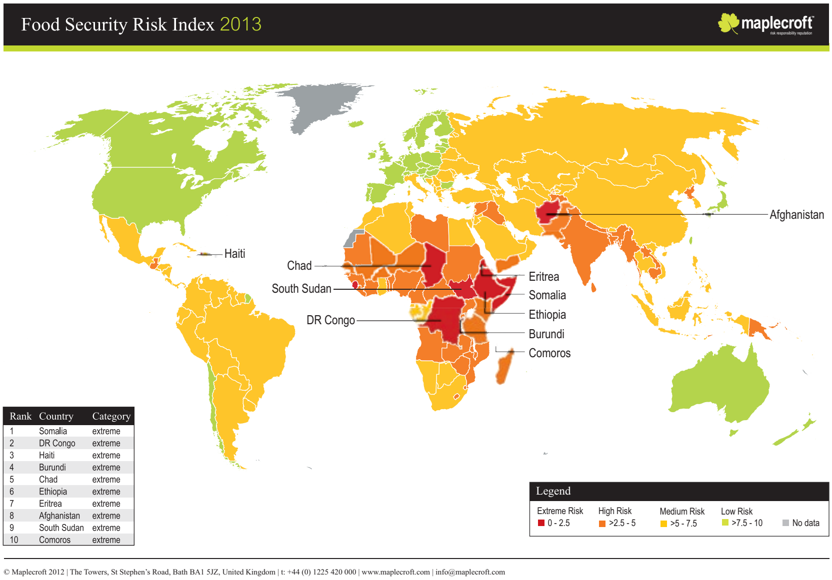

Fig. 1.5 Food insecurity is not uniformly distributed. Areas of extreme risk (red on this map) are mostly in Africa or in war-torn regions such as Afghanistan

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 mention 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).

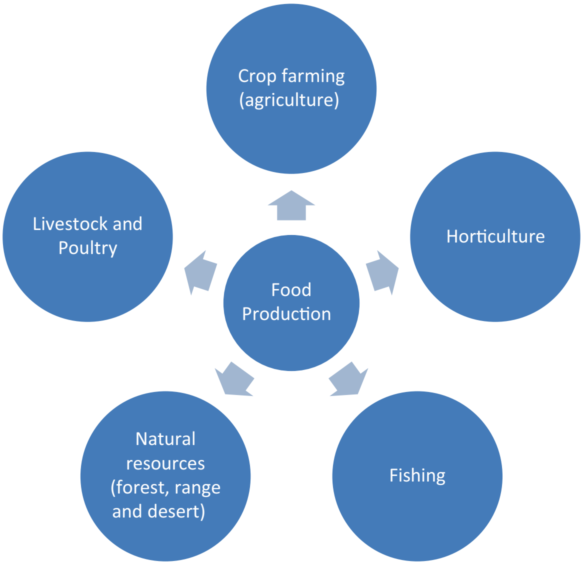

Fig. 1.6 Different sectors of food production

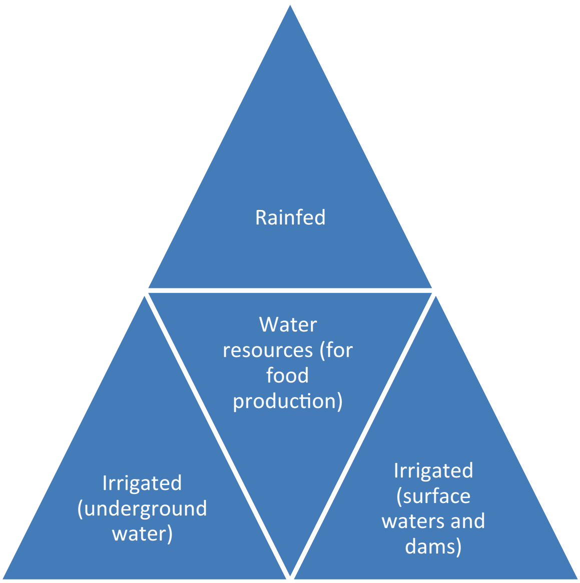

Fig. 1.7 Water resources to be used for food production

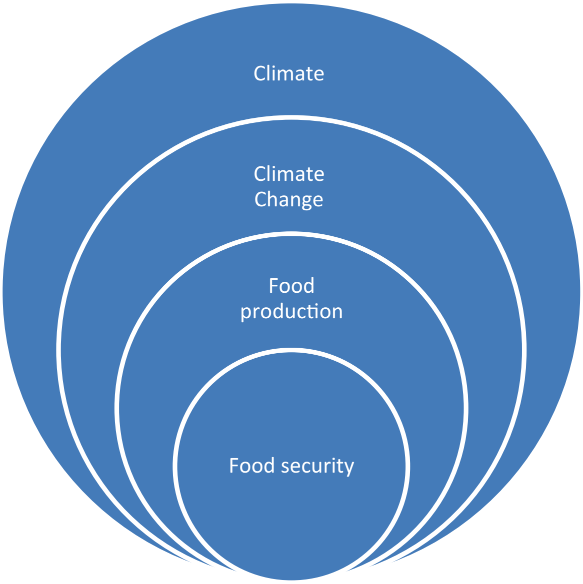

Fig. 1.8 Interaction between climate change and food security

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.

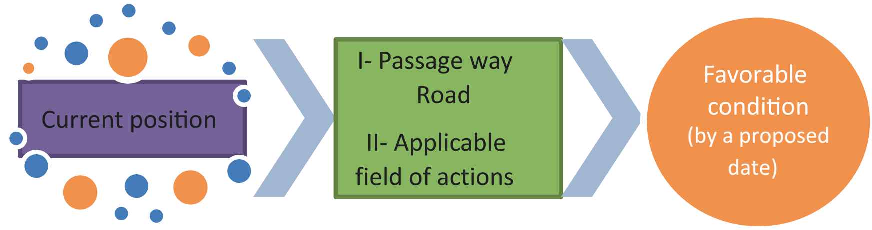

Fig. 1.9 Strategic road map of climate change and food security

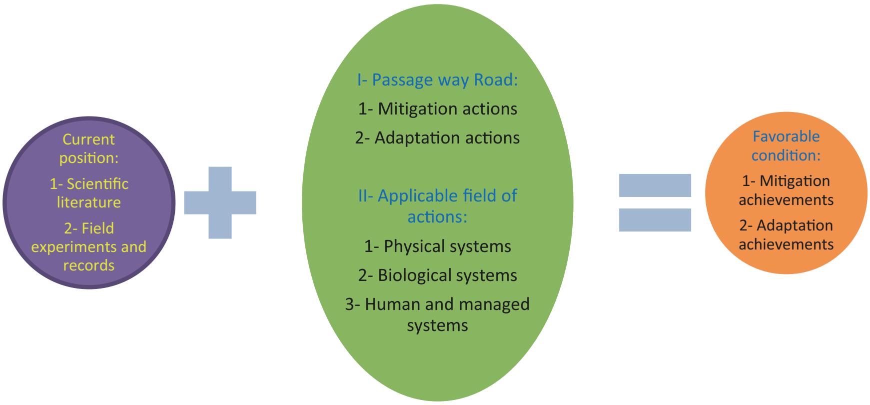

Fig. 1.10 Important advances in resilience policy and strategies

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Chapter 2
Commentary on Challenges to Taking a Food Systems Approach Within the Food and Agriculture Organization (FAO)

Mohammad Hossein Emadi and Maryam Rahmanian

Introduction

Achieving food security and nutrition worldwide has been a global concern since the 1930s and in fact provided the impetus for the creation of the United Nations' Food and Agriculture Organization in 1945. This goal, articulated as reducing the number of the hungry by half by 2015, has been adopted in numerous global summit declarations (the World Food Summit in 1996 and the World Food Summit: five years later in 2002) as well as the Millennium Development Goals. The Sustainable Development Goals increased the ambition and set a goal of ending hunger and all forms of malnutrition by 2030. Despite promising developments in reducing hunger for some years, more recent trends are worrying. According to the latest SDG progress report, an estimated 821 million people – approximately 1 in 9 people in the world – were undernourished in 2017, up from 784 million in 2015 (UNSG 2019). This represents a worrying rise in world hunger for a third consecutive year after a prolonged decline. Overweight and obesity continue to increase in all regions (FAO et al. 2019). In 2016, 131 million children 5–9 years old, 207 million adolescents and 2 billion adults were overweight. Of those who were overweight, a third of adolescents and adults and 44% of children aged 5–9 were obese.

A focus on agricultural productivity has dominated global efforts to achieve food security, including the work of the Food and Agriculture Organization (FAO) of the United Nations, for several decades. Despite important work showing the availabil-

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ity of sufficient quantities of staple foods and the lack of access of the poor to food (Sen 1981), investments have continued to focus on increasing productivity, mirroring the prevalence of export-led agricultural policies around the world. Projections of global population growth, some predicting a population of 10 billion by 2050, regularly bring renewed calls for new sophisticated technologies or the further exploitation of shrinking natural resources to increase production. The International Panel of Experts on Sustainable Food Systems has identified “feed the world” narratives as one of the important lock-ins that is keeping the industrial food system in place and hindering efforts to diversify food and agriculture systems (IPES-Food 2016).

The need to take a food systems approach, one that would look beyond increasing agricultural productivity, started gaining in prominence during the last decade. Particularly since the global food price spikes of 2007–2008, and new challenges posed by climate change, obesity, food losses and waste to name a few, the scientific and policy communities have focused their attention on multiple problems within global food systems. The High Level Panel of Experts on Food Security and Nutrition (HLPE 2014) has defined a food system as “all the elements (environment, people, inputs, processes, infrastructures, institutions, etc.) and activities that relate to the production, processing, distribution, preparation and consumption of food, and the outputs of these activities, including socio-economic and environmental outcomes.” Besides understanding the linkages between the activities of various actors in the food system, from production to processing and consumption, food systems must also be understood as shaped by power imbalances among those actors (IPES-Food 2015).

In line with this “systems approach”, as a holistic approach that considers multiple issues and their dynamic interrelations, a number of recent initiatives have put the issue of appropriate food policies on the table in Canada (Food Secure Canada), Europe (IPES Food) and in cities (the Milan Pact). Some of these initiatives mention production (always placing the emphasis on sustainable production), but they also raise the importance of issues such as sustainable diets, shorter and fairer supply chains, trade, equity, food waste, culture and identity and the right to food. Many of these initiatives also place importance on process-related issues, such as the importance of inclusivity and cross-departmental governance structures to develop and implement effective food policies (IPES, Milan, Canada).

The term food system started to enter FAO’s vocabulary since about the 2010s (see, for instance, FAO’s Medium Term Plan 2010–13). In 2012 FAO hosted an electronic consultation on “Linking Agriculture, Food Systems, and Nutrition”. Also in 2012, FAO presented a Reviewed Strategic Framework which presented five Strategic Objectives, the fourth of which was “Enable more inclusive and efficient agricultural and food systems at local, national, regional and international levels”. The emphasis here was on connecting smallholders to increasingly globalized markets, demonstrating a fairly narrow conceptualization of “food systems” as one that is close to the concept of value chains. The 2013 FAO publication, the State of Food and Agriculture, focused on food systems and nutrition and was an influential resource for putting the topic on the global agenda.

An internal reorganization led to the establishment of the Nutrition and Food Systems Division in 2015. In 2016, FAO included nutrition as a new cross-cutting issue in its results framework.[1] Linking nutrition with wider agricultural policies is not new to FAO, but it has not had the prominence that agricultural production has enjoyed. The 1943 conference that led to the establishment of FAO concluded that food policy and the agricultural policies of the nations must be considered together. A historical review of FAO's attempts to link nutrition and agricultural policies can be useful to understand the challenges that FAO faces in taking a food systems approach.

Historical Context

League of Nations

In the early 1930s, the League published a highly regarded scientific report on nutrition (the Interim Report of the Mixed Committee) (Way 2013). At that time, the focus of the League on health and nutrition was greater than on agriculture. It is interesting to note that this report focused overwhelmingly on malnutrition in developed countries (Ruxin 1996). Following from this, and responding to growing recognition of the importance of nutrition for health, the League appointed an international nutrition officer (Phillips 1981).

The interest in nutrition was driven by science, which at that time identified specific vitamins and for the first time made the link between the absence of these vitamins and certain diseases. Dietary standards incorporating these early discoveries were devised in the 1920s. With a standard established, it was possible to calculate the cost of an adequate diet. Surveys following establishment of dietary standards in the 1920s showed that substantial proportions of populations, even in advanced countries, could not afford a diet adequate for health (Way 2013).

In 1935 the Assembly of the League of Nations discussed a memorandum entitled "The Agriculture and the Health Problems". This memorandum analysed the causes of agricultural problems, argued the benefits of improved nutrition and called for a reorientation of agricultural policy, meaning that industrial countries should concentrate on producing more nutritious "protective foods" (e.g. dairy products, vegetables and fruit), benefiting both consumers and producers. This was proposed as the "marriage of health and agriculture" and went against the accepted policy beliefs at the time, according to which the problem of farm incomes could be addressed through import quotas, production limits, protective tariffs and pooling schemes to keep prices high. The proposal was to keep the highly nutritive, "protective foods" (e.g. dairy products, vegetables and fruit) within the purchasing power of the poor by increasing food production and lowering its price (Way 2013).

[1] See http://www.fao.org/3/a-mm710e.pdf.

According to John Boyd Orr, the first Director General of FAO, "The growing demand to get the new science of nutrition applied for the improvement of the health and physique of the nation calls for a reconsideration of the Government agricultural policy … a State agricultural policy must form part of a national food policy, the basis of which must be the provision of a diet adequate for health for every member of the community" (Quoted in Ruxin 1996).

In 1937 the League of Nations produced a report on *The Relation of Nutrition to Health, Agriculture and Economic Policy* (cited by Phillips 1981), which became a bestseller among League publications (Way 2013). One of its 15 recommendations was to promote steps to improve and cheapen marketing and distribution of protective foods. Although immediate changes in government policies were negligible (except for the formation of national nutrition committees in some 40 countries), nutrition became a subject of wider public debate and education (Way 2013).

This approach to nutrition clashed with economic and commercial policies. Tension developed between measures to raise agricultural prices and efforts to improve health. Concerned doctors and scientists met with the resistance of governments who feared the cost of acting to ensure healthy nutrition for all. At the same time, industry was promoting the health benefits of various foods, such as milk in the USA, and successfully increased consumption several fold (Way 2013). The purpose, however, was to meet the economic needs of agriculture, rather than the health needs of the population.

Establishment of FAO: Nutrition and Agriculture Linkages Are Key

Efforts to address hunger globally by the League of Nations were interrupted by WWII, which did, however, bring the problem of hunger into sharp focus, on the one hand by interrupting production and trade and on the other with the latest science of the time showing that nutrition was a necessary condition for success in war by supporting the health of soldiers. It was during this period of crisis that the establishment of FAO was planned. The proponents of the nutrition approach at the League of Nations spent the war years taking their ideas to the USA, where they met with support (Way 2013). They proposed an international food organization to promote the increased consumption of food along the lines indicated by the latest nutrition science and steps towards reconciling national policies on agriculture and commerce with nutrition policies. They tried to convince US leaders to convene an international conference by promoting food security and nutrition as a means of preventing post-war conflicts of interest.

President Roosevelt convened the United Nations Conference on Food and Agriculture at Hot Springs in May 1943 (UN, 1943). This Conference laid the groundwork for the establishment of the Food and Agriculture Organization of the United Nations in October 1945. An Interim Commission on Food and Agriculture was established which prepared the FAO constitution, and five technical reports were prepared to explore and propose activities of the soon to be established FAO. One of these was on nutrition and food management. Nutrition was also prominent on the agenda of the Conference. Recommendations focused on topics including the improvement of national diets; diets of vulnerable groups; malnutrition and disease; deficiency diseases; national nutrition organizations; and dietary standards (Phillips 1981).

The Final Act of the Hot Springs Conference put nutrition as central in its vision for a world free of want. The 1943 conference declaration was very significant for its strong emphasis on bridging food and agriculture, stating that a substantial increase in food production would be needed but stressed that quality of product was important as well as quantity (UN, 1943). The Conference emphasized the importance of "secure, adequate and suitable supply of food" and frequently referred to the need for "more and better food" with "greater emphasis on foods rich in vitamins, minerals and proteins". The conference's first priority was guaranteeing sufficient calories but "preferably done by means of a variety of foods so that appreciable amounts of other nutrients are contributed to the diet" (Fanzo and Byerlee 2019).

"The work of the Conference emphasized the fundamental interdependence of the consumer and the producer. It recognized that the food policy and the agricultural policies of the nations must be considered together" (Final Act, p.1). The Declaration has several sections (indeed the first ones) that focus on nutrition: improvement of national diets, diets of vulnerable groups, malnutrition and disease, deficiency diseases, national nutrition organization, and dietary standards. The Final Act recommends each country to develop a national food and nutrition policy, to the full fruition of which related social and economic policies will need to be adopted (Final Act, p.33). "One other agricultural and economic consideration, which has received attention in other reports, is the need for shifting the emphasis in many countries from the production of cash crops to food crops for human consumption. Land, time and effort should, in particular, be given to the production, near to the consumer, of those foods of high nutritive value which, at the same time, are perishable and difficult to transport and distribute" (Final Act, p.42).

Following some preparatory work after the Conference, the FAO was established as the first permanent specialized agency of the United Nations, in October 1945 with the objective of eliminating hunger and improving nutrition and standards of living by increasing agricultural productivity.

First Years of FAO: Fading Support for Linking Agriculture and Nutrition

Reflecting divergent views about its role among member countries, FAO's constitution was ambiguous, generally favouring an advisory role but allowing room for an executive interpretation. In reality, trade and commodity interests prevented FAO from playing a truly global coordination and strong governance role. Powerful countries (Britain, USA) were not prepared to hand over decision-making authority to an overarching organization that they did not fully control. In the years after World War II, FAO made several attempts to propose international systems of coordination on agriculture policies, including the ambitious World Food Board (McDonald 2018).

The World Food Board attempted to respond to the need to stabilize the agricultural situation in the long term by organizing production, distribution and consumption to prevent both shortages and surpluses. The main idea was to stabilize world market prices of agricultural products in order to incentivize expanded production. This proposal was based on the proposal that FAO would operate buffer stocks to stabilize the prices. At the core of the World Food Board lay the notion that increased trade with all its attendant benefits would only materialize in regulated markets, not in a resort to a free market (Jachertz 2015).

The proposal for a World Food Board, which was put forward very soon after FAO's establishment, identified two main problems: insufficient nutrition on the one hand and agricultural production on the other, particularly in "expensive foods of special value to health" such as milk, eggs and meat (McDonald 2018). US and British opposition to the proposal forced the establishment of a preparatory commission to consider other proposals (Way 2013; Staples 2006). Their opposition was based on the position that agricultural trade should fall within the responsibility of the proposed International Trade Organization (which never got off the ground), rather than the FAO (Jachertz 2015). Ultimately FAO was unsuccessful in overcoming the reluctance of member nations to give up national control and sovereignty over even a limited aspect of agriculture and food production.

Overall Evolution of FAO Shaped by Political and Economic Interests of Its Member Countries and Their Global Interactions

Following its initial years, the evolution of FAO's role has continued to be strongly shaped by political developments and the relative power of different groups of countries, often developed versus developing, or more recently commodity importing versus exporting countries (McKeon 2015; ETC Group 2009). Another source of tension is between national sovereignty on the one hand and internal coordination and collective decision-making on the other. The interests of different groups of countries have kept important issues, such as trade, off the table and have always hampered attempts to take an approach that sees the interlinkages between various aspects of food systems.

Seeking to avoid these tensions, in its first decades, FAO focused on laying the foundations for its future work through gathering data, for instance, by conducting the first world food survey in 1946 and the world census on agriculture in 1950. It also addressed more urgent issues related to food shortages.

During the 1960s which heralded the decolonization movement and the formation of the G-77[2] in 1964, which called for a New International Economic Order and strongly supported UNCTAD and the UN Centre on Transnational Corporations, FAO was seen as an important tool for developing countries to pursue their common interests. The emphasis of FAO's approach during this period on supporting national self-reliance through food stocks, as well as regional cooperation, reflected the revitalization of developing country efforts in using FAO for their own purposes. However, once again this approach was challenged by the major grain-exporting countries (USA, Canada and Australia) and influenced by only five companies which controlled the grain trade (Jarosz 2011).

An oil price hike and poor harvests brought about a global food crisis in the 1970s and gave countries concerned with FAO's policy directions the opportunity to delegate important roles to other, newly founded institutions. FAO's food aid, finance and research functions were divided up and delegated to newly created institutions without the one nation/one vote rule that governs FAO. Beginning in the 1960s, FAO's role in agricultural research was undermined, and despite opposition from FAO, the Consultative Group on International Agricultural Research (CGIAR) was formed in 1971 outside the UN System and headquartered at the World Bank. Financial support role of FAO as a funder of agriculture and rural development was handed over to the newly established International Fund for Agricultural Development (IFAD), and the World Food Programme (WFP) was separated from its original home in FAO to cover food emergency role. During this period the USA proposed the formation of a new global governance body for food and agriculture to be called the World Food Council. While its role was kept deliberately vague, the presumed intent of the WFC was to take over the policy-setting functions of FAO. The ineffective World Food Council was finally discontinued in 1993 (ETC Group 2009).

The creation of the CGIAR reflected the emphasis placed during this period (and still to this day) on agricultural science and technology to increase productivity. The Green Revolution made major contributions to agricultural productivity and reducing hunger from the 1960s (although its environmental impacts have come under strong criticism in recent years), and FAO concentrated on programmes for the development of high-yield strains of grain, the elimination of protein deficiencies, the provision of rural employment, and the promotion of agricultural exports.

Starting in the 1980s, the emphasis was put on trade liberalization and economic growth as a way to replace food stocks, supply management and subsidies, which were seen as a means to ending poverty and hunger and achieving development. International financial institutions imposed structural adjustment programmes on debt-ridden developing countries, forcing them to open their markets to global trade and to reduce their support to agriculture. Self-sufficient countries in the developing world were transformed into importing countries. The economic upheaval caused

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[2] The Group of 77 (G-77) was established on 15 June 1964 by 77 developing countries signatories of the "Joint Declaration of the Seventy-Seven Developing Countries" issued at the end of the first session of the United Nations Conference on Trade and Development in Geneva.

by these programmes was to be addressed with food aid. The G7/8 emerged as an important promoter of these policies, and the World Trade Organization was established in 1995. At the same time, corporations and market integration grew, as did the influence of corporations on global food policies. From the 1980s to the mid-2000s, governments persisted in the belief that world hunger was no longer an issue. As a result, funding for agricultural and rural development collapsed, there was underinvestment in national agricultural research in most countries, and multinational corporations consolidated horizontally and vertically in industrial food chains (ETC Group 2009).

At the same time, the 1980s and 1990s saw an increased interest in equity and rights issues, driven in part by the research of Nobel prize winner Amartya Sen which showed that hunger was not driven by lack of food supplies, but by social and economic realities of the lives of the poor. One strand of policymakers and other advocates called for a shift in thinking from "food supply" to "access to food" (although the attention to increasing productivity did not subside). Poverty alleviation and social protection programmes emphasizing food staples were prioritized. The World Food Summit Declaration aimed to create the basis for food security at the individual, household, national, regional and global scales. The Declaration affirmed the right of people everywhere to have access to safe, nutritious and adequate food as well as the right to be free from hunger. However, opposition on issues related to the environment and the limitations of the productivity paradigm, rural poverty, food sovereignty and human rights also grew during this period.

From the mid-2000s, the negative impact of two decades of structural adjustment programmes became undeniable. In 2005 the Doha round of negotiations at the WTO was effectively blocked due to disagreement on agricultural issues. In 2008 the World Bank's World Development Report admitted that insufficient attention had been given to the contribution of agriculture to economic growth. The 2007–2008 world food crisis hit in this context and helped to bring back to the table issues such as food stocks, the role of agriculture in economic growth and poverty reduction (in particular smallholder farming) and human rights. In April 2008, the Secretary General of the UN established the UN High Level Task Force on the Food Security Crisis. The crisis also led to the establishment of a new body to address gaps in food security and nutrition governance with increased inclusion and transparency: the reformed Committee on World Food Security (2009). The reform of the CFS renewed hopes in a fair and accountable system of food governance, but the political problems that have been evident since FAO's establishment have also emerged in the CFS and, as a result, hope that the CFS will not only be able to discuss controversial issues such as trade but also influence the actions of the relevant institutions, is waning.

FAO's governance structure, which gives each member state one vote regardless of population and economic and political power, has been seen by some member countries as an inhibitor or threat to pursuing their own global agricultural trade interests and objectives. This led to a progressive weakening of FAO which generally continues to this day, as seen in the tendency of major donor countries to limit their contributions to the regular programme of FAO based on nominal budget (which is controlled by collective decision of all member countries and is fixed during last decade) and focus on the extra-budgetary contributions, which are severely directed or controlled by the contributor's preferences or interests.

Nutrition Within the Overall Evolution of FAO

As mentioned above, the initial post-war idealism and enthusiasm for a global institution which would deliver on nutrition through reorienting and globally coordinated agricultural policies was strongly opposed and lost steam in the first years after FAO's establishment. Despite FAO's constitutional commitment to improving the nutritional status of the world population, the Nutrition Division was dwarfed as other parts of the organization grew and expanded. In 1955, FAO's budget for its Nutrition Division represented only 5–6% of its total expenditures and consistently had the smallest budget of the five FAO divisions. While the reason for this dramatic decline in attention to nutrition is not clear, there is some indication that this was due to lack of requests for support on nutrition from member countries (Ruxin 1996). The work of the other divisions focused on more tangible production-related issues, such as animal disease control and crop production, which gained more support from the governmental delegates representing their countries in FAO's governing bodies, usually from the ministries of agriculture.

FAO's work on nutrition has tended to steer clear of controversial issues such as trade. FAO collects and publishes statistical material on the production and consumption of food worldwide and has played a part in many transnational ventures aimed at formulating global standards. Together with the WHO, FAO elaborated nutritional requirements which were used to assess if food production was keeping pace with nutritional needs and discussed the use of food additives. Also in partnership with the WHO, FAO established the Codex Alimentarius in 1963, the international agreement which sets the global standard for food safety.

In the 2000s, FAO's work on nutrition included (i) scientific advice including food composition and nutrient requirements; (ii) information, assessment, analysis and statistics; (iii) integration of nutrition into field programmes including nutrition education and community-based nutrition; (iv) policy assistance; and (v) normative work (FAO 2011).

The Independent External Evaluation of FAO found that the Organization's work in food policy does not adequately integrate nutrition considerations and, equally, that its work on nutrition has been conducted in isolation from work on economic, social and food policy (FAO 2007). Similarly, the 2011 evaluation of FAO's work on nutrition concluded that FAO suffers from a siloed approach to nutrition and that nutrition is not well integrated into the work of the other divisions and departments (FAO 2011). The current Strategic Framework includes nutrition as a cross-cutting theme, but in practice there is very little integration of nutrition in work related to production. Of equal concern, the evaluation found that FAO had performed weakly at articulating how agriculture and food-based approaches can contribute to tackling hunger and malnutrition, taking into account the double burden of undernutrition and overnutrition (FAO 2011).

In 1992 and again 2014, FAO partnered with WHO to convene the first and second World Conference on Nutrition to raise policy attention to nutrition. The latter led to the Rome Declaration on Nutrition which calls for trade policies to be conducive to fostering food security and nutrition for all, through a fair and market-oriented world trade system, but does not say how this system should come about. The follow-up, the UN Decade of Action on Nutrition (2016–2025), has developed a Work Programme that has an action area on trade and investment for improved nutrition, but again it is quite vague, and it is not clear who is responsible for implementing the Work Programme.

The latest FAO Mid Term Program (MTP) shows FAO's attempt to articulate the connection between nutrition and food systems. FAO locates several drivers of the global obesity and non-communicable diseases epidemic within food systems, from primary agricultural production (intake of various chemical contaminants, toxins and antimicrobials present in food and water) to consumption (the composition and nutritional quality of diets) (FAO MTP June 2019). Issues related to world trade, and global commodity prices, are not however included in FAO's food systems approach to nutrition.

Nutrition Issues Today: New Challenges for FAO

The Sustainable Development Goals (SDGs) replaced the MDGs and heralded a new global move towards a comprehensive, multidimensional and holistic approach to addressing food security, hunger and malnutrition. The SDGs were both bolder and broader in their approach to eliminating hunger and malnutrition than any previous international efforts. They reintegrated agriculture, diets and health as a vital solution to the problem of malnutrition. This integration inherently requires more complex multidimensional approaches to addressing hunger and nutrition by all UN agencies including FAO, and the attempt should go well beyond food availability and access to achieve food security throughout food systems.

Nutrition and health issues have changed greatly over the past decades. There is evidence that almost half of the global burden of disease and more than half of all annual deaths are related to diet-related diseases (WHO 2002). At the same time, the poor are feeding on empty and cheap calories which fuel obesity. As people everywhere are cooking less and eating more processed foods, the role of the private sector, which is increasingly consolidating its control of entire food chains, is expanding.

Discussion

At a time when a "food systems" approach is becoming a policy focus for the FAO, in particular, and the UN in general, it is interesting to note that the proposal of linking food (and nutrition) policies and agricultural policies in a coherent way is not new and was even central at the time of the establishment of FAO. However concerns about the high costs of nutritious diets and the loss of sovereignty of countries (that were asked to submit their agricultural policies to a global coordination body) blocked progress in this area. This shows that linking different objectives (in this case nutrition and agriculture) is a challenging and political task, and this is precisely what is required when taking a comprehensive, holistic and systemic approach.

Although FAO's policies may seem incoherent and inconsistent to outside observers, this is largely a result of its role in mediating the opposing interests and growing conflicts within global context and eventually among its membership. These are increasingly shaped by the growing role of the private sector with the rise of large, concentrated international food industry and mega or multinational corporations. It is their effective lobbying systems and power that often dictate government's formal political positions and capital's vote.

Trade is a fundamental part of most food systems today, and as the nature of global trade changes, new challenges arise for the global institutions that have a role in regulating it. In the last 70 years, there have been huge changes both in agricultural production systems and also in markets and trade. First because of lower transport and energy costs and other policies, trade is totally globalized and happens at very high levels. So trade issues have become more complex and essential for major producers and consumers of food and agricultural products. Environmental and climate change also is making current challenging situation worse and undermining food system in general and food supply side in particular which will impact trade particularly in fragile developing countries (IPCC 2019).

There are different blocs of countries: low labour and resource costs, high labour costs and importance of environmental issues. In recent decades these blocs have been shifting as it is no longer north versus south given that there are also several countries with rapid growing economies, low labour costs and relatively plentiful environmental resources. The labour, resources and products of these countries are being used by other countries which have environmental protection legislation and higher labour standards, while also having access to raw materials and inexpensive labour through expanded global trade and low-cost transportation.

Economic events and international trade generally affect food system and nutrition, depending on the extreme poverty level, and inequalities in income distribution and also the overall performances of national economy. Economic slowdowns and downturns during 2011–2017 period pose major challenges for food sector and nutrition, creating constant escapes and increasing inequalities (FAO 2019). On the other hand, the international agreements and regional trade commitments are fading, and role of the WTO is rapidly declining, though it is not able to intermediate the different interests of its members any longer. In such global settings, FAO even through its normative mandate is unlikely to be able to play a noteworthy role in trade of food and agriculture because its members, today as in the past, are not likely to compromise and accept having less authority in such a chaotic unpredictable situation. The intensive election process and unexpected result of the newly (2019) elected Director General of FAO could be considered as the reflection of the above mentioned polarising global context and the diverse trend of member countries.

Notwithstanding this limitation, one possible way of promoting a more systemic approach to food security and nutrition would be to open up policy discussions to multidisciplinary approaches and interdisciplinary platforms.[3] All major relevant stakeholders beyond agriculture, such as health and environment, need to be involved in this process. The inclusion of a wider number of relevant sectors (beyond simply agriculture) may take more time and longer procedures but will cause shifts in alliances between countries and would lead to new process and eventually surprising outcomes called "emergent properties" in systems thinking.

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Chapter 3
Agricultural Productivity and Food Security

Victor R. Squires and Mahesh K. Gaur

Background and Context

Land quality varies and determines, to a large extent, the land use systems adopted in a region or area. Figure 3.1 is a map showing the distribution of land classes across the globe. Table 3.1 reflects the areal extent of each land quality category and percentage of population occupying the various land classes. Links between land quality[1] agricultural productivity and food security are intuitively reasonable but complex. Empirical analysis of these links has historically been limited by data constraints and disciplinary boundaries (Wiebe 2003). Agricultural productivity affects food security through its impacts on both food supplies and farmers' incomes. Food security per se also influences farmers' practices that affect land quality over the long term.

Despite the challenges we must gain a better understanding of the projected changes in land quality, land degradation, agricultural productivity, and food security at the policy-relevant scale. We need to consider the role of the farmers' decisions, not just in terms of maximizing income in the short term but also in terms of sustaining income over the longer term by investing in the maintenance or improvement of land quality. This applies whether we are dealing with small-scale subsistence farmers or farmers driven by commodity prices in the commercial farming world.

[1] Land quality refers to the ability of land to produce goods and services that are valued by humans. This ability derives from inherent/natural attributes of soils (e.g., depth and fertility), water, climate, topography, vegetation, and hydrology, as well as "produced" attributes such as infrastructure (e.g., irrigation, transportation routes) and proximity to population centers.

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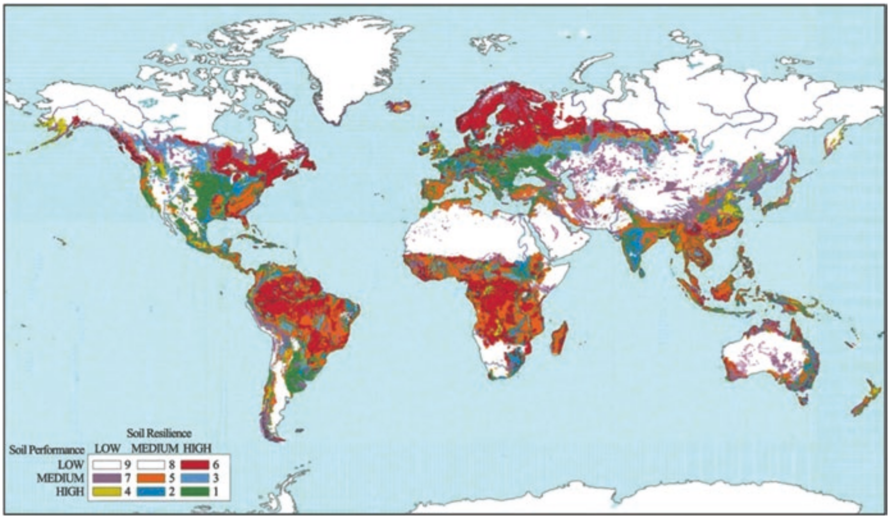

Fig. 3.1 Global distribution of major land quality classes (Class 1 is the good-quality land). (Source: Eswaran et al. 2003)

Table 3.1 Global land quality apropos land surface area and population distribution

Land quality class	Total land surface in each class	Percentage of global population occupying each land class
1	2.4%	6.1%
2, 3	9.5%	19.0%
4, 5, 6	33.8%	53.6%
7	9.0%	11.5%
8, 9	45.3%	13.1%

Source: Blum and Eswaran 2004

The result is not a simple linear relationship that begins with exogenous land quality and traces causality through to agricultural productivity and food security in a single period, but rather a dynamic process in which each element influences the others over time (Fig. 3.2).

Just as land quality includes climate and hydrologic characteristics that affect land's ability to provide goods and services, land degradation includes changes in those characteristics—including water resources—that reduce land's ability to produce goods and services (Fig. 3.3). Depletion of water resources poses at least as important challenge for agricultural productivity and food security as do the more commonly considered aspects of land degradation and soil loss (see chapter by Nagabhatla et al. this volume). The number of water-scarce countries is projected to grow from 20 in 1990 to 35 in 2025, while the number of people living in water-scarce countries is projected to increase by 0.1 billion to 0.8–1.1 billion over the same period. It has been concluded by Wiebe (2003) that land degradation appears

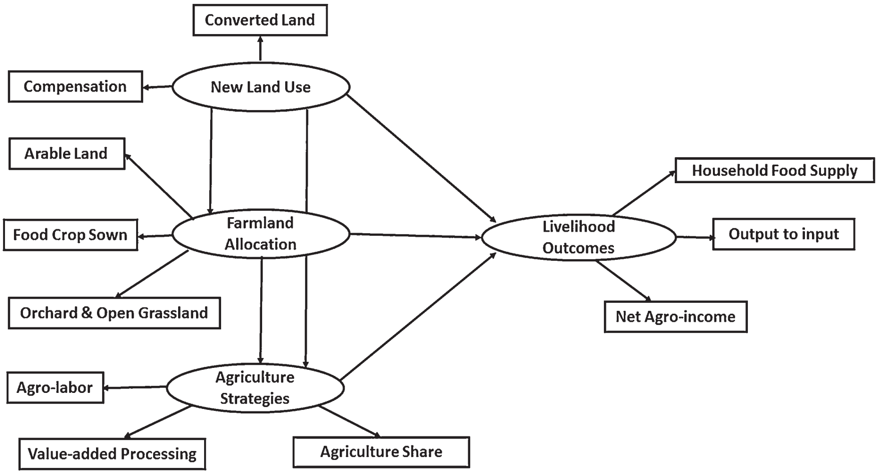

Fig. 3.2 Smallholder agricultural systems are complex. Livelihood (far right) depends on the favorable co-occurrence of a number of seemingly unrelated factors (far left) of this diagram and is moderated by policy interventions (center) and farmer responses. (Source: Modified from Li et al. 2016)

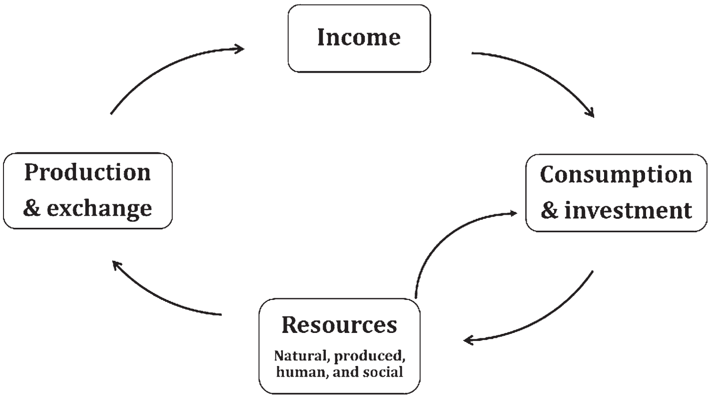

Fig. 3.3 Opportunities, choices, and outcomes in resource use and food security. Modified from Maxwell and Wiebe 1999

to generate productivity losses that are relatively small on a global scale but that both productivity losses and their food security consequences are likely to be significantly greater in area where fragile resources are found in conjunction with poverty and poorly functioning markets and institutions.

Land, and especially soil, degradation is an important factor to consider when assessing the world food situation. Soil degradation can adversely impact food security by reducing agricultural productivity, especially in regions with resource-poor farmers who cannot afford to apply inputs at recommended levels (Lyu et al.

2019). The adverse impacts of soil degradation on agricultural productivity and food security are compounded and exacerbated by the scarcity of water for agriculture. At the same time, food consumption patterns (see below) are important drivers of environment degradation, e.g., unsustainable water use, declining soil fertility, marine environment degradation, biodiversity loss, greenhouse gas (GHG) emissions, climate change (CC), etc.

Impact of Changes in Dietary Patterns on Food Security

The Lacirignola et al. 2014 review paper explores the natural resources-food nexus by highlighting the environmental footprints of the current consumption and production patterns. The current consumption patterns imply high ecological, carbon, and water footprints of consumption and unfavorable national virtual-water[2] balances. Food Balance Sheets data show that the contribution of vegetal and animal-based food product groups to food supply is variable, but the demand for the latter is growing rapidly on a global basis. Immediate action is required to address environmental degradation that is mainly driven by population and consumption. Stress on biological as well as social systems is exacerbated by unsustainable consumption patterns, in particular food consumption patterns that are important drivers of environment degradation, e.g., unsustainable water use, declining soil fertility, marine environment degradation, biodiversity loss, climate change (CC), etc.

Much of today's discourse about environmental problems revolves around reducing greenhouse gas (GHG) emissions and water usage. Development cannot be "sustainable" except if the fundamental common goods are protected and improved. Protection of the coast, sea, climate and air quality, soil and biodiversity, water resources, cultural and landscape heritage, and traditional knowledge of nature is the priority to be focused on. It is very important to break the joints that make economic development reliant on an intensive exploitation of natural resources and to promote changes in consumption and production patterns. In this context, the current food system delivers low-cost food at a high cost to the environment, and this cost includes also environmental impacts of food production, distribution, and consumption. As a very important factor in critical sustainability issues, diets affect different factors (social, cultural, agricultural, environmental, nutritional, and economic) which interact with one another. In fact, many issues (water, biodiversity loss, scarcity, soil erosion, etc.) are linked to food consumption patterns, and it should be addressed as priorities. There are signs that diet has an impact on health, but the sustainability of food consumption and food systems appertains to environmental impacts. If no changes are implemented in the coming years, there is a high risk of further deterioration of the global food system with consequent degradation of the environment and the natural resource base.

[2] Virtual water refers to the amount of water used in the production of a crop or an end product, e.g., 1 kg of rice or beef and even a cotton shirt.

A push toward a more plant-based diet world wide could also potentially save substantial amounts of greenhouse gas emissions. If people ate more plants, in line with standard dietary guidelines, it would have a positive effect on diets and on the environment, reducing global mortality by 6–10% and food-related greenhouse gas emissions by 29–70%. Tapping into the planetary wealth of diverse fruits, vegetables, pulses, and grains, particularly nutrient-dense varieties, can address both overweight and micronutrient deficiencies (Box 3.1 lists some of the merits of a diet based on a broader range of food plants).

Box 3.1 Food is the Vehicle for Getting Micronutrients into Our Bodies

- More healthy options within food groups—expanding the range of fruits, vegetables, whole grains, nuts, seeds, pulses. Biodiversity is recognized as a fundamental principle in recent dietary guidelines like the Mediterranean Diet Pyramid, the Nordic guidelines, and the Brazilian guidelines.
- Important and significant nutritional differences between species. For example, in Bangladesh, although people started eating more fish, their nutritional intake decreased from eating exotic farmed fish rather than nutrient-dense local fish. Then there are species many people have never heard of—gac (*Momordica cochinchinensis*), for example, is a fruit from Southeast Asia with extremely high levels of beta-carotene, which the body converts to vitamin A.
- Important and significant nutritional differences within species. For example, some bananas are orange and contain very high levels of beta-carotene; others are white and contain none. Different varieties of potato can contain between 6 mg and 37 mg of vitamin C.
- Since many less well-known plants, fish, animal, and trees are well adapted to local environments, they can be more tolerant to low inputs or climate fluctuations and so can be selected to provide a portfolio of nutritious foods all year round, integrating small animals, green vegetables, and fruit trees.
- Food has to be accessible, affordable, acceptable, and available. Food biodiversity is often all four. To address it, food, health, and agriculture policies need to be linked to one another.

Land Degradation and Changes in Land Use and Agricultural Productivity Over Time

Agricultural productivity at various spatial scales changes over time as a result of changes in land quality. Planning horizons are intimately related to farmers' property rights/use rights in land. Poverty also plays an important role in the management of marginal and often fragile lands (both cropland and grazing land). Most studies on the effects of land degradation focus on selected measures of productivity, but land degradation may affect food security as well, through its impact on food production as well as on incomes and food prices.

A 2015 UN report[3] warned that climate change has already curtailed global food production and millions are at risk of poverty and hunger in the coming years. The report suggests that funding for climate mitigation is best spent on changing agricultural practices. Organic agriculture is one important arm of this approach (see below). Considering the global demands of increasing cost of mineral fertilizers, the use of organic amendments (OAs) including manures, composts, crops residues, and biosolids is rapidly increasing, and their share of agricultural land and farms continues to grow in many countries. For example, about 32.2 million hectares (ha) of world arable land were managed organically using mainly OAs by more than 1.2 million growers (Willer and Kilcher 2009). Oceania, Europe, and Latin America are the regions with the largest organically managed land areas. Application of OAs is regarded as one of the most promising options to increase farmers' income by restoring soil fertility and, at the same time, by protecting the environment. Organic agriculture possesses several advantages such as improving plant growth and yield, soil carbon (C) content, and microbial biomass and activity and preventing desertification by improving soil structure and fertility. Nevertheless, OAs applications possess some disadvantages such as nutrient eutrophication and GHG emission (Willer et al. 2009).

Climate Change Poses Risks to Global Food Security

Climate change has already begun to affect the world's food production, a new report from the United Nations warns—and unless significant action is taken, it could put millions more people at risk of hunger and poverty in the next few decades. It's a message that's been emphasized over and over by climate scientists and has informed many of the UN's sustainable development goals and positions on global food security. But 2015 was the first time it has been the primary focus of the UN Food and Agriculture Organization's annual *State of Food and Agriculture* report.

Box 3.2 Climate Change Exacerbates the Risks of Hunger and Undernutrition and May Generate Extreme Weather Events

- 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. Climate-related disasters have the potential to destroy crops, critical infrastructure, and key community assets, therefore deteriorating livelihoods and exacerbating poverty.
- **Long-term and gradual climate risks**
  Sea level will rise as a result of climate change, affecting livelihoods in coastal areas and river deltas. Accelerated glacial melt will also affect the

(continued)

[3] http://www.fao.org/publications/sofa/2015/en/

Box 3.2 (continued)

quantity and reliability of water available and change patterns of flooding and drought.

Food security and nutrition (climate change affects all dimensions of food security and nutrition)

- **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.
- **Food access:** Climate change could increase the prices of major crops in some regions and affect *affordability*. For the most vulnerable people, lower agricultural output means lower incomes. Under these conditions, the poorest people—who already use most of their income on food—sacrifice additional income and other assets to meet their nutritional requirements or resort to poor coping strategies.
- **Food utilization:** Climate-related risks affect calorie intake, particularly in areas where chronic food insecurity is already a significant problem. Changing climatic conditions could also create a vicious cycle of disease and hunger. Nutrition is likely to be affected by climate change through related impacts on food security, dietary diversity, care practices, and health.
- **Food stability:** The climatic variability produced by more frequent and intense weather events can upset the stability of individuals' and government food security strategies, creating fluctuations in food availability, access, and utilization.

Climate change is likely to impede progress on reducing undernourishment around the world in the decades ahead, according to a scientific assessment released by the US. Department of Agriculture (USDA) during the 21st Session of the Conference of Parties to UN Framework Convention on Climate Change (COP 21) in Paris. "Climate Change, Global Food Security, and the U.S. Food System," which was prepared as a contribution to the National Climate Assessment, represents a consensus of 31 authors and includes contributors from 19 Federal, academic, nongovernmental, and intergovernmental organizations in four countries. It identifies climate change effects on global food security (the ability to obtain and use sufficient amounts of safe and nutritious food) and the challenges facing farmers and consumers in adapting to changing climate conditions.

The report found that climate change is likely to cause disruptions in food production and a decrease in food safety, which in turn leads to local availability limitations and increases in food prices, with these risks greatest for the global poor and in tropical regions. Accurately identifying needs and vulnerabilities and effectively targeting adaptive practices and technologies across the full scope of the food system are central to improving global food security in a changing climate.

Box 3.3 Main Findings of the Report on Climate Change, Global Food Security, and the U.S. Food System

- Climate change is very likely to affect global, regional, and local food security by disrupting food availability, decreasing access to food, and making utilization more difficult.
- The potential of climate change to affect global food security is important for food producers and consumers in the United States.
- Climate change risks extend beyond agricultural production to other elements of global food systems that are critical for food security, including the processing, storage, transportation, and consumption of food.
- Climate risks to food security increase as the magnitude and rate of climate change increase. Higher emissions and concentrations of greenhouse gases are much more likely to have damaging effects than lower emissions and concentrations.
- Effective adaptation can reduce food system vulnerability to climate change and reduce detrimental climate change effects on food security, but socioeconomic conditions can impede the adoption of technically feasible adaptation options.
- The complexity of the food system within the context of climate change allows for the identification of multiple food security intervention points, which are relevant to decision-makers at every level.
- Accurately projecting climate change risks to food security requires consideration of other large-scale changes.

There is growing alarm among scientists and policymakers over the dire threat climate change poses to future food security, best described as a vicious cycle in which unsustainable farming practices contribute hefty greenhouse gas emissions to the atmosphere and drive more warming. This can then continue to hurt global crop production. Under a severe climate change scenario, FAO points out, research suggests that 122 million more people could be living in extreme poverty by the year 2030 compared to a future with no climate change. Even under a low-impact climate scenario, this number could be as high as 35 million more people. According to FAO, while the impact of climate change on agriculture is expected to become increasingly severe in all parts of the world post-2030, the most vulnerable populations include producers (especially smallholders) in developing countries whose livelihoods depend on farming (Squires et al. this volume). Global declines in production may also radiate throughout the world in the form of higher food prices, placing a greater strain on already vulnerable low-income communities.

Agriculture, forestry, and land use changes, taken as a whole, are responsible for about one fifth of all global GHG emissions. So adopting more sustainable farming practices and preventing deforestation, which often takes place to clear land for agriculture, can help mitigate climate change from the ground up. Lal (2004) showed that soil C sequestration is a strategy to achieve food security through the improvement of soil quality. It is a by-product of the inevitable necessity of adopting recommended management practices (RMP) for enhancing crop yields on a global scale. While reducing the rate of enrichment of atmospheric concentration of CO_2, soil C sequestration improves and sustains biomass/agronomic productivity. It has the potential to offset fossil fuel emissions by 0.4–1.2 Gt C/year, or 5–15% of the global emissions. Concern has been expressed about the huge contributions of GHG attributed to the meat industry alone—from the methane produced by cattle, in particular—and to the sheer amount of land and resources required to raise livestock. Farm animal production accounts for about 18% of the world's GHG emissions, especially of methane and nitrous oxide (Steinfeld et al. 2010; Moumen et al. 2016)

Although there is some doubt about the practicality of switching to a vegetarian-based diet, calculations do show that even based on today's farming systems it would be technically possible to feed 10 billion persons in 2050, but many commentators fail to see how it is at all practical to promote vegetarianism unless reinforced by a belief system, and it is certainly not the direction of global diets. As Falvey (2012) says "Western diversionary magazines that claim a rise in vegetarianism conveniently omit rises in meat consumption in developing countries that are multiples of any reductions resulting from fads in food secure Western countries.[4] But it does highlight how far from reality that anecdote-informed thought can be, even though it can influence international aid policy." It is worth reflecting too on the much-praised Indian vegetarianism and to acknowledge that apart from plant-based foods, milk and eggs play an important part in the daily diet. As the world population rises, the demand for meat, eggs, and dairy products is soaring in developing countries. Both production and consumption of animal products are increasingly concentrated in developing countries. In fact, the demand in those countries has increased at a staggering rate in recent decades. There are two main reasons for the increase—urbanization and rising incomes particularly in developing and emerging countries. China, Brazil, and India have all seen their middle class or consumer class rise over the last 30 years. And what tends to happen when people have a little bit more money to spend is they spend it on higher-quality food. They tend to buy more milk or cheese or meat. The increase in meat consumption in developing countries is understandable. In the developing world, particularly sub-Saharan Africa and in Asia, meat can be a tremendous boost to people's diets. It can provide important nutrients that they weren't getting before, especially for malnourished populations; and it can really help people, especially children, develop better. Policies for food and seeds of food plants need to shift the focus from maximizing yield and profit to also including considerations of diets and nutrition. Brazil is a great example of this. Brazil has recently targeted several policies to promote local and indigenous biodiversity for food and nutrition as part of its Zero Hunger campaign. Actions taken in Brazil

[4] https://www.voanews.com/a/decapua-farm-animals-29mar12-144898655/…

include promoting diverse, healthy native foods in dietary guidelines, supporting production of food biodiversity through public procurement strategies (e.g., for food in schools), and prioritizing food biodiversity in relevant national strategies, action plans, agriculture, and nutrition policies.

Farm animal production provides a "safety net" for millions of vulnerable people (Squires and Bryden 2019a; Suhubdy et al. this volume). However, production often also takes place on factory farms, feedlots, and other concentrated animal feeding operations (CAFOs). The demand is being met by industrial animal operations or factory farming (Squires and Bryden 2019b). This is a style of farming that really originated in Europe and the United States in the 1950s and 1960s, where thousands or even tens of thousands of the animals are confined in feedlots, huge barns, or sheds. This type of mass animal production can need a lot of resources or inputs to operate and require a lot of fossil fuel energy for heating and cooling. They require tremendous amounts of soy and corn for animal feed and depend on antibiotics to keep these animals healthy, although in countries like Australia, residues of antibiotics and other chemical compounds are strictly monitored (Harper et al. 2019). Factory farms (chickens, pigs, beef cattle, dairy cattle) produce huge amounts of waste, which can contaminate groundwater.

Climate Change Mitigation and Adaptation

Climate change is one of the most complex issues facing us today. It involves many dimensions—science, economics, society, politics, and moral and ethical questions—and is a global problem, felt on local scales, that will be around for decades and centuries to come. Responding to climate change involves two possible approaches: reducing and stabilizing the levels of heat-trapping greenhouse gases in the atmosphere ("mitigation") and/or adapting to the climate change already in the pipeline ("adaptation"). The goal of mitigation is to avoid significant human interference with the climate system and "stabilize greenhouse gas levels in a timeframe sufficient to allow ecosystems to adapt naturally to climate change, ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner" (from the 2014 report on Mitigation of Climate change from the United Nations Intergovernmental Panel on Climate Change, page 4, Smith et al. 2007). Adaptation—adapting to life in a changing climate—involves adjusting to actual or expected future climate. The goal is to reduce our vulnerability to the harmful effects of climate change (like sea-level encroachment, more intense extreme weather events, or food insecurity). It also encompasses making the most of any potential beneficial opportunities associated with climate change (e.g., longer growing seasons or increased yields in some regions). It is important to learn how to best manage land and forests, how to deal with and plan for reduced water availability, and how to develop resilient crop varieties.

Forms of Adaptation in Response to Climate Risks

According to Agrawal and Perrin (2008), a policy-relevant framework for examining adaptation practices in the context of rural institutions and livelihoods needs to be sufficiently general to cover the many empirical examples of adaptation practices used by different social groups but also needs to be based on an analytical approach that takes into account the most important characteristics of the impacts of climate change on rural livelihoods—likely increases in environmental risks, reduction in livelihoods opportunities, and stresses on existing social institutions (Fig. 3.4).

Climate change is likely to manifest around increased risks to rural livelihoods. These risks can be classified into four different types: across space, over time, across asset classes, and across households. The basic coping and adaptation strategies in the context of livelihoods risks can correspondingly be classified into a set of four analytical types: mobility, storage, diversification, and communal pooling. In addition, where households and communities have access to markets, market-based exchange can substitute for any of the four classes of adaptation strategies above (Agrawal and Perrin 2008; Halstead and O'Shea 1989). Where successful, these responses either reduce spatial, temporal, asset-related, and/or community-level risks directly or reduce them by pooling uncorrelated risks associated with flows of livelihoods benefits from different sources. Mobility is perhaps the most common and seemingly natural response to environmental risks. It pools or avoids risks across space and is especially successful in combination with clear information about potential precipitation failures. Storage pools/reduces risks experienced over time. When combined with well-constructed infrastructure, low levels of perishability, and high level of coordination across households and social groups, it is an effective measure against even complete livelihood failures at a given point in time. Diversification reduces risks across assets owned by households or collectives. Highly varied in form, it can occur in relation to productive and non-assets, consumption strategies, and employment opportunities. It is reliable to the extent that benefit flows from assets are subject to risks and risks have different impacts on the benefit streams from different assets.

Communal pooling refers to adaptation responses involving joint ownership of assets and resources; sharing of wealth, labor, or incomes from particular activities across households; or mobilization and use of resources that are held collectively during times of scarcity. It reduces risks experienced by different households. Exchange is perhaps the most versatile of adaptation responses. Usually it is viewed as a means to promote specialization and increase revenue flows. But it can equally substitute for the first four classes of adaptation strategies to reduce risks when the poor have access to markets. As a means to reduce risks, it can go together with high levels of specialization and institutionalization of exchange relations: consider as an example, buying insurance to cover risks of crop failure. Resorting to exchange or promoting exchange-based adaptation to address climate risks needs however to be treated with some caution given the highly unequal access to markets across different social groups, especially those who are in marginalized situations. The success,

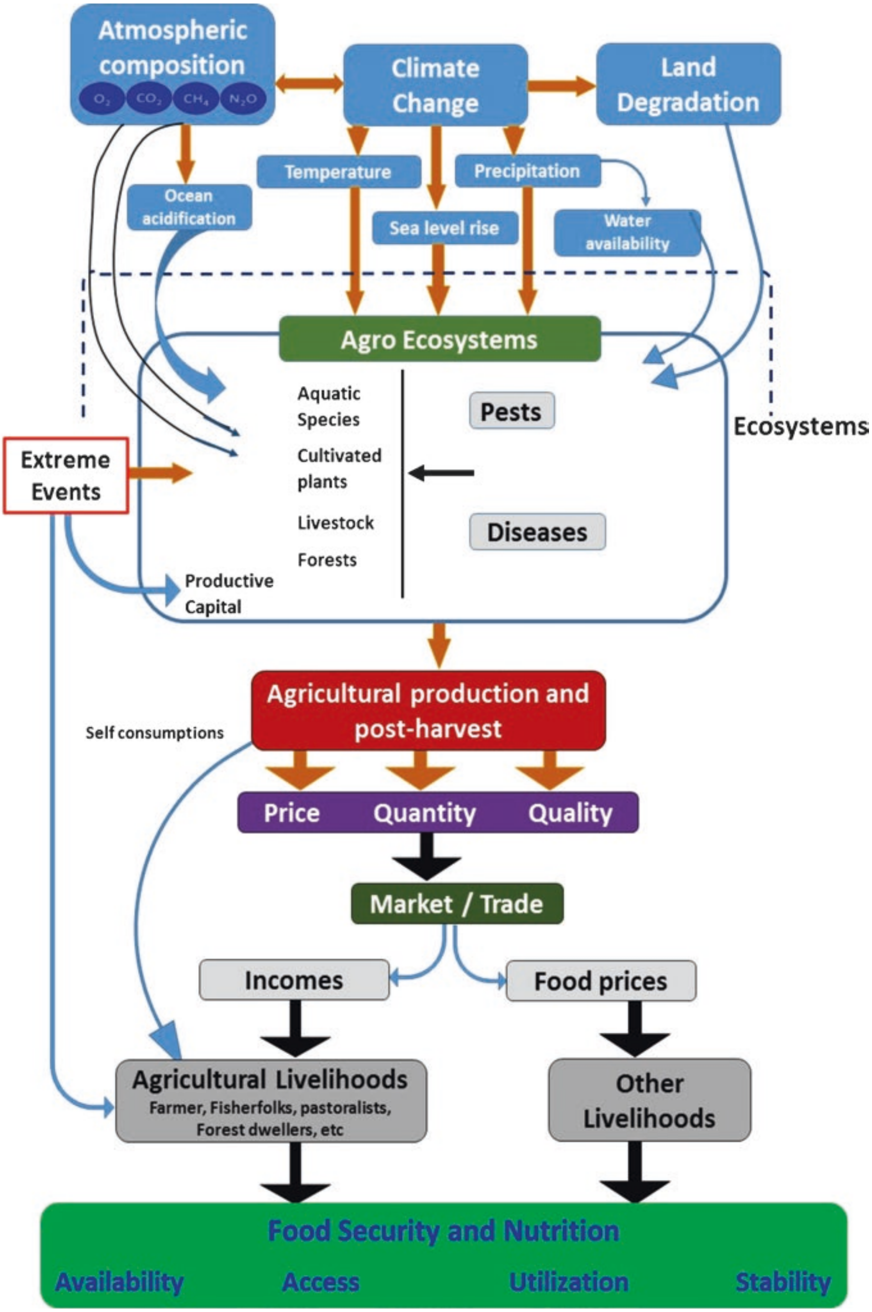

Fig. 3.4 The interplay between climate change, food production, and nutrition is multi dimensional

and more generally the prospects of adaptation practices, depends on specific institutional arrangements—adaptation never occurs in an institutional vacuum. Thus, all adaptation practices require property rights, norms of trust are necessary for exchange, storage requires monitoring and sanctions, mobility cannot occur without institutions that provide information about the spatial structure of variability, and agricultural extension institutions can facilitate diversification. The adoption of adaptation practices by specific households and communities is more or less likely depending on their social and economic endowments, networks of relationships, and access to resources and power. For example, the poor are more likely to migrate in response to crop failure and the rich more likely to rely on storage and exchange (Agrawal and Perrin 2008).

Preparation for the impact of climate change could include diversifying the types of crops farmers raise, researching and adopting more heat-resistant plant varieties, and investing in better soil conservation techniques, which may help prevent some of the production losses expected in a warming world (Gaur and Squires 2018). All of these strategies will require greater investments from the international community. IFRI suggests that more of the funds intended for climate mitigation should be directed into the agriculture sector. Making these investments may be critical if the world is to meet the global climate goals set forward in the Paris Agreement—namely, keeping warming within at least a 2-degree temperature threshold. Recent studies have suggested that greenhouse gas emissions from farming must fall by a billion tons per year by the year 2030 if the world is to stay on track to meet agreed targets. Smallholder farmers are a special case that involves 2 billion people worldwide. Smallholders operate in a complex and unpredictable system of climatic, economic, political, environmental, and social conditions and constraints (Squires et al. this volume). Yields and farmer incomes are constrained by low soil quality, limited infrastructure, and poor access to markets for inputs and produce. Smallholder farmers are targeted by multiple poverty alleviation and development strategies, including international food security and environmental initiatives and financing sources, such as GEF.

Climate-Smart Agriculture (CSA)

Elements of agroforestry, conservation agriculture, livestock, aquaculture, post-harvest, and food energy systems are captured by the term CSA.

FAO (2013) has defined climate-smart agriculture (CSA) as: "*CSA is Agriculture that sustainably increases productivity, enhances resilience (adaptation), reduces/removes GHGs (mitigation) where possible, and enhances achievement of national food security and development goals*."

Therefore, it is an approach that helps to guide actions needed to transform and reorient agricultural systems to effectively support development and ensure food security in a changing climate. The CSA concept aims at three targets to achieve:

1. To increase agricultural productivity to support increased incomes, food security, and development
2. To increase adaptive capacity at multiple levels (from farm to nation)
3. To decrease greenhouse gas emissions and increasing carbon sinks (Campbell et al. 2014)

CSA options include both on-farm and beyond-farm agricultural and landscape management activities but also require addressing the mediating institutions, finance, and policies. CSA proponents claim that because of its broadly supported goals, CSA should be upscaled, play a central role in agricultural strategies, and be integrated with the wider social-ecological system to ensure effective use of resources (Sayer et al. 2013), for example, as pursued under the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). This requires coordination at farm or community levels, as well as landscape levels (Scherr et al. 2012). CSA would have to be integrated with existing landscape approaches, which have already been adopted in policy for several sectors.

Agrobiodiversity Is Key to Nutrition and Sustainability

Agrobiodiversity, or the biological diversity of food, can improve food system resilience, sustainability, and nutrition. A 200-page report[5] titled *Mainstreaming Agrobiodiversity in Sustainable Food Systems* outlines how biodiversity can help us produce foods that are both nutritious and sustainable. The edible plant and animal species that feed each and every one of us holds the key to future food security. Of the 30,000-ish plant species that can be used as food, today only three—rice, wheat, and maize—provide half the world's plant-derived calories. A focus on a handful of starchy staples has contributed to an increase in land planted with maize, wheat, and rice from 66% to 79% of all cereal area in the world between 1961 and 2013. Of concern too is that the genetic base of even these three crop species has narrowed. Wild progenitors of wheat, rice, and maize and countless other food plants are at risk (Emadi 2019). There is a risk that using a single variety across vast areas leaves such crops open to attacks by pests and diseases. To counter this, the industry and farmer response is often to use large quantities of pesticides, fungicides, and so on, which is expensive as an input, has a negative impact on environmental factors such as water quality and (wild) biodiversity, and has high fossil fuel inputs. Fortunately, smallholders across Asia, Africa, and Latin America (who collectively produce more than half the world's food) are the custodians of a treasure trove of local genotypes of food plants and livestock (Xia et al. 2010; Squires et al. 2019). At the same time, the same pressures that are driving the sixth mass extinction of wild biodiversity are also affecting agricultural biodiversity—habitat transformation, deforestation, invasive species, and climate change. They also lead to disruption in pollinators and natural pest control. Loss of wild biodiversity can lead to erosion of genetic

[5] https://www.cornucopia.org/2017/10/agrobiodiversity-key-nutrition-sustainability/

diversity (like the wild relatives of crops, which are a valuable source of traits for breeding), which reduces options for breeding new plant varieties better adapted to climate change. We should point out though that there is no way yet to accurately measure the decrease in agricultural biodiversity. It is notoriously difficult to measure the exact status of crop and animal genetic diversity. A study in 2014 classified 58% of domesticated animal breeds as of unknown risk status. Also for crops, there are huge data gaps—number and distribution of species and their genetic diversity—so it is difficult to determine genetic erosion. One challenge is the richness of the diversity—even if we consider only the 150–200 crops commercially cultivated, it is hard to identify, monitor, and conserve it all.

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Chapter 4
Water and Food Security Crisis Influencing Human Mobility Patterns: A Comprehensive Overview

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Introduction

The theory and practice of managing land and water interactions for ensuring food and water security are inherently complex. The multifaceted challenges manifested from the impacts of water scarcity/crisis or food insecurity often span multiple facets, including "ecological" "social" "cultural" and "political" and are inherently interdisciplinary. In this context, understanding the current and emerging trends of human mobility, both locally and internationally, remains a challenge. Migration has traditionally been explained as a collection of "push" and "pull" factors that include social, economic, political, and environmental aspects applicable to human

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security, economic opportunity, peace, and political stability. It is becoming increasingly evident that prolonged episodes of water and food insecurity are acting as a "push" factors for human mobility. Thus, these push factors can lead to various and severe spill over impacts, viz conflict, disruption of security, peace and political instability, and migration (e.g., forced mobility) (Nagabhatla et al. 2014; Le Billon and Duffy 1994; Puma et al. 2018). Besides, a lack of integrative and adaptive guidelines for managing water and food crisis scenarios exacerbates the complexity in examining patterns of human mobility (Food and Agriculture Organization of the United Nations 2017).

The combination of push and pull factors, depending on whether they are acting independently or in tandem, determines the complexity of human mobility interlinkages with land, water, society, and geopolitics. Gleick and Iceland (2018) discuss how varied aspects of water-related risks and threats exacerbate the risk of conflict. For instance, prolonged or/and cumulative effect of reduced or disrupted water supply or water quality concerns, surge in water demand, and extreme flood events, can cause food insecurity and result in displacement of vulnerable communities. Furthermore, increasing conflicts and rights-tenure-ownerships challenges and how these challenges interface customary laws and legal policies of the state further exacerbate the vulnerabilities. The livelihoods and income generation of communities and populations, who are exposed to food, water, and climate crises are at risk. Additionally, facets of power, ownership, and rights to food and water, ethnic complexities to land and water access, contemporary policies versus customary regulations, and poor land and water governance are set of direct and indirect "drivers of" human mobility links with water and food crisis (Puma et al. 2018).

The decision to migrate by persons and populations, either within their own countries or across borders, is influenced by a complex set of these factors. Moreover, migrants who transit within a state or across borders for work and survival can encounter various challenges depending on whether they migrate voluntarily or are forced to leave due to events that threaten their safety or livelihoods. The lack of integrative and adaptive guidelines for managing water and food crisis scenarios exacerbate the complexity in addressing the food-water-human mobility nexus. Knowledge of this nexus is limited both in literature and practice. World Water Development Report (WWAP 2019) acknowledges that better understanding the interlinkages between water-food crises and human development can prove helpful for addressing multifaceted challenges in conflicts areas and to aid individuals and populations living in vulnerable situations (WWAP 2019).

Human mobility phenomena have seen a significant rise across various locations worldwide and are referenced in the emerging body of literature on water, food crises, and climate change (Food and Agriculture Organization the United Nations 2018; The Asian Development Bank 2012). The Global Risks Reports organized by the World Economic Forum (2016, 2017, 2018) mentions that enhanced understanding of the impacts of water and climate crisis is critical to ensure economic, financial, political, and human security for communities and states. Increasingly, researchers and policymakers are seeking to explain human mobility flows driven by water scarcity and food insecurity – often perpetuated by climate change (Jägerskog et al. 2015). Noting that the human mobility patterns are increasing at a fast rate, it is pertinent to understand the direct and indirect drivers of migration which stem from water and food crises and its interlinkages with other contributing forces. Very few to none of the national or global agreements address the multidimensional trends and patterns of human mobility (Laczko and Piguet 2014).

In this context, and for enhanced understanding of the interlinkages of this nexus, this chapter adopts a three-tier approach. The first tier outlines diverse narratives to explain human mobility and displacement driven by food and water crisis scenarios in different socioecological, sociocultural, and sociopolitical settings with a focus on Asia and Africa. The second tier unpacks how migration trends and patterns connect to water and food crisis scenarios. The third tier employs a case study approach (Congo Basin region) to illustrate the interlinkages in water security, food production, and human mobility in settings of conflict. In this region, the multifaceted drivers of conflicts are expected to increase pressure on land and water resources and are influencing new patterns of human mobility. Overall, the chapter highlights the relatively under-examined scenarios stemming from water and food crisis and provides a guideline framework to assess multiple dimensions of human mobility, food and water insecurity, and political instability – while connecting to the sustainable development agenda.

Background and Setting: Water and Food Security Crisis and Human Mobility Nexus

Water and food crises are intertwined, and if the balance in allocation, conservation, and proper management of land and water resources is not addressed, the risk for water and food insecurity increases. Distress, poverty, conflicts, and human mobility may further ensue as indirect outcomes. Human mobility at the global scale has been increasing since 1990, wherein digital records show around 140 million migrants. In the past years, international migration worldwide has increased from 173 million (2000) to 222 million (2010) and 244 million (2015). This worrying trend is projected to increase in 2050 to one billion (United Nations Department of Economic and Social Affairs 2017). Most of these numerical trends are rooted in conflicts and disaster as the critical push factors. Conflicts are also connected to the control, allocation, distribution, or pricing of food and water. For instance, agriculture is the world's largest consumer of freshwater resources and accounts for nearly two-thirds of annual water withdrawal for irrigation, livestock, and aquaculture.

Moreover, 20% of freshwater resources are consumed by industries, including for energy generation. Finally, domestic supply accounts for the remaining fraction (FAO 2017). The water footprint of food is high. For example, 3000–5000 liters (l) water are used for 1 kilogram (kg) of rice, 2000 liters are used for 1 kg of soya, 900 liters are used for 1 kg of wheat, and 500 liters (l) are used for 1 kg of potatoes (WWF 2003). As >80% of the global arable land is rainfed and contributes to >half of global food production, the influence of adverse impacts of climatic variability on food production from agriculture is a vital dimension in human mobility. This holds especially with respect to migration from rural to urban regions (Mastrorillo et al. 2016).

Interlinkages between water and food crises and human mobility are fairly debated in the literature, with some development reports indicating that water and food insecurity represents a crucial driver of human mobility (Food and Agriculture Organization of the United Nations 2016; Black et al. 2011). The IPCC has outlined some initial drivers of human mobility, including coastal erosion and flooding, increasing salinity and temperatures, rising sea levels, increases in the number and severity of extreme weather events, water scarcity, and glacial melting. It was argued that these drivers compromise the habitability of environments worldwide and impact agricultural viability, infrastructure and services, the stability of governance, and existing human settlements (Solomon et al. 2007). Also, economic and financial shocks further reduce access to food and water, affecting their pricing. This, in turn, can lead to undesired pathways of human displacement, mainly as a result of critical disruption of livelihoods and income generation, and disruption of community's resilience. Human mobility or displacement is often seen as a coping strategy or a survival response in such scenarios (Luginaah et al. 2009; Deshingkar 2012; Warner and Afifi 2014; Schmook and Radel 2008). The interconnections between land, water, and climate factors, and environmental change is also influenced by, and influences conflict, livelihood opportunities, and other drivers of migration. That, in turn, makes it difficult to clearly state the ultimate factors that determine the decision to migrate (Asian Development Bank 2012; Black et al. 2011; Lilleø and Van den Broeck 2011; Martin 2013). Combined with a lack of clear international legal definitions about environmental migration, it contributes to a lack of data and makes it further challenging to estimate how water, food, and climate crisis is driving human mobility (Black 2001).

The available literature on interlinkages between human mobility, food and water security, hunger, poverty, and inequality highlights how primary and supplementary drivers manifest in a specific context, including sociopolitical and sociocultural settings (Food and Agriculture Organization of the United Nations 2016; Black et al. 2011). Environmental and financial stocks tend to reduce access to food and increase food costs. Such situations, coupled with weak institutions and lack of opportunity for income generation, also contribute to people's decision to migrate (Luginaah et al. 2009; Deshingkar 2012; Warner and Afifi 2014; Schmook and Radel 2008). Water scarcity also drives water pricing (Rios et al. 2018). Most impoverished communities often reported paying 5–10 times more per liter of water than affluent communities, and as such, vulnerable populations suffer more from a lack of access and availability of water and food (WWAP 2019). Sometimes, these settings lead to conflicts and thereby increase the risk of unplanned human mobility. Thailand's worst flooding in half a century produced economic damages and affected people's livelihood and increased their economic vulnerability. For example, the automotive and electronics industries were significantly impacted, which disrupted global supply chains for certain critical products for months. In total, Thailand reported overall damages >$45 billion (the World Bank 2012). Similarly, the devastating rainfall across South Asia (August 2017) led to >1000 deaths and directly affected >40 million people in northern India, southern Nepal, north of Bangladesh, and southern Pakistan (Gleick and Iceland 2018).

The standard guidelines, legal structure, or conceptual framings on "environmental migrants" "displaced person" and "refugee" are lacking, and consequently, there is no common ground on which the systematic progress on addressing related "drivers" and managing "responses" can be displayed and shared. This, in turn, poses challenges to examining empirical evidence which is required for effectively addressing water and food crisis-driven human mobility. The IOMs definition of environmental migration reflects the duality of compulsion and choices along a single continuum (Francois Gemenne 2009) and integrates the distinction between sudden and slow-onset disasters, internal and international movement, and temporary and permanent relocation (Renaud et al. 2011). Human mobility is an umbrella term for diverse sorts of movements of people; the reasons behind such movements can be various. Human mobility pathways that may be voluntary, involuntary, short or long term, short or long distances, within countries or across borders can involve individuals, households, and communities (Ober 2019). The standard conceptual underpinnings and terminologies of the migration literature as shown in Table 4.1 are adopted in this manuscript.

A clear understanding of interventions, strategies, and institutional arrangements to tackle food and water crisis can facilitate planners, managers, and the policymakers to appropriately address gaps and needs in planning response mechanisms for

Table 4.1 Framings from the migration literature that apply to human mobility driven by water and food crisis

Internally displaced people (hereafter referred to as IDPs)	Apply for people who are displaced, or have fled, from their home to find safety but remain within their home country's borders (UNHCR 2017)
Returning migrants	Applied to people who return to their home country after being IDPs or international migrants and intend to stay there for some time (OECD 2001)
Environmental migrants	Persons or groups of persons who, predominantly for reasons of sudden or progressive change in the environment that adversely affects their lives or living conditions, are obliged to leave their habitual homes, or choose to do so, either temporarily or permanently, and who move either within their country or abroad (IOM 2013)
Refugees	A popular quote in the current migration literature – one example is the case of IDPs where displacement is classified as "forced." The concept got recognition in the 1951 Refugee Convention
Internal migrants	Persons who migrate within the country that they reside, with focus on rural to urban movements, while international migrants are persons living in a country outside their place of birth

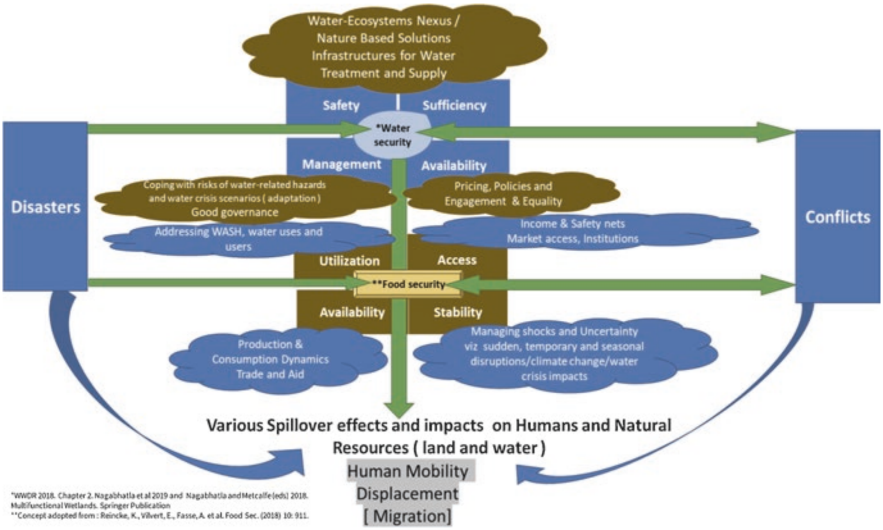

Fig. 4.1 Conceptual layout of crucial dimensions and interlinkages in the water-food crisis planning and how it operates within the disasters and conflicts conditions, (dark color externalities or conceptual keystones and light color operational mechanisms)

situations of conflicts, human mobility, displacement, and migration. Development initiatives and policy interventions need to align closely with community and stakeholder needs, particularly for populations living in vulnerable situations. These include scenarios of conflicts, in and across sectors, particularly land and water resources. A comprehensive account of the interlinkages between human mobility pathways (reflecting externalities, conceptual framings and interlinkages), water, and food crises is sketched in Fig. 4.1.

Additionally, the synthesis attempts to capture the complexity inherent to this nexus in alignment with the sustainability targets. The post-2015 ambitions encapsulated in the 2030 Agenda, with 17 goals and 169 targets, aim to steer communities, societies, states, and countries to balance development, growth, and well-being in domains of social, ecological, economic, health, and politics. Also, it calls for integrated planning to address contemporary changes and their spillover impacts. Nilsson et al. (2018) argues that there are a lot of synergies and trade-offs within the SDGs and how efforts are geared to implement the SDG goals and targets can serve as a critical mechanism for assembling, systematizing, and aggregating knowledge on interactions, interlinkages, future potential, barriers, and opportunities in food, water, and human mobility-related challenges and needs. For instance, the mandate outlined in SDG 2 (food focused), SDG 5 (gender-focused), SDG6 (water-focused), and SDG 13 (climate change-focused) points to climate, water, and food crisis, as well as ecosystems degradation and how these relate to challenges faced by resource-dependent communities and individuals.

The Assessment Approach: A Three-Tiered Framework

Tier 1: Analyzing Diverse Narratives in Human Mobility and Food and Water Crisis Scenarios with a Focus on Asia and Africa

Framing narratives for an enhanced understanding of this nexus is a challenging task for researchers and experts involved in migration research. US. Office of the Director of National Intelligence (DNI) reports on the global and regional water security challenges and states that "the lack of adequate water will be a destabilizing factor in some countries because they do not have the financial resources or technical ability to solve their internal water problems." In many instances the underlying driver of water crisis is "a crisis of governance," which requires rigorous emphasis on capacity building within government strategies on water resource management. We present an aggregation of multiple narratives as a tool to explain pluralistic dimensions and interlinkages that apply to land and water resources such as allocation, ownership, rights, policies, and associated human mobility in Annexure 1.

The additional narratives position migration destinations that host large migrant communities in informal settlements that are in turn influenced by a range of socio-economic and environmental vulnerabilities. These environments are a result of the overarching lack of capacity that serve as an additional stressor of mobility. A vicious cycle is formed where migrants aim to adapt to several vulnerabilities caused by inadequate and imbalanced capabilities (at individual and systems, e.g., governance level) to manage natural resources, livelihoods, and socioeconomic development. In turn, migrants with low capacity have a high risk of getting trapped in vulnerabilities at their destination settlement, due to similar capacity-related imbalances (Niva et al. 2019). The increase in short-term migration, where women and children seek work to supplement household incomes, is also noted (Henry et al. 2004). In 1994, the "Program of Action of the International Conference on Population and Development", held in Cairo, marked an event steering international debate on migration and human mobility. They stated that "Governments are encouraged to consider requests for migration from countries whose existence, according to available scientific evidence, is imminently threatened by global warming and climate change" (United Nations Population Fund 1994).

Facilitating the stated need, Walter Kälin, the Secretary-General on the Human Rights of IDPs, urged for an in-depth analysis of the different contexts and forms of displacement induced by natural disasters. Five displacement triggering scenarios (Fig. 4.2) were identified which were adopted by the Inter-Agency Standing Committee Working Group on Migration/Displacement and Climate Change (Kälin 2008). These scenarios can be adapted to analyze human mobility patterns.

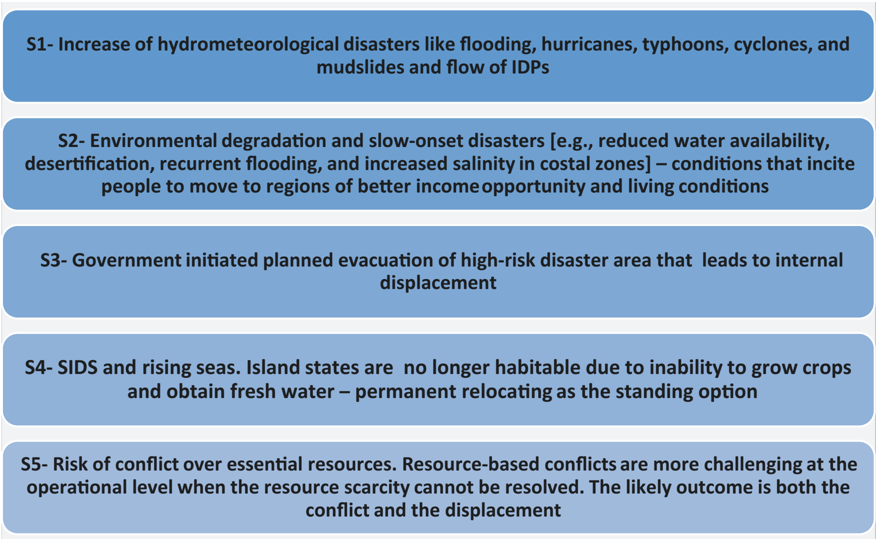

Fig. 4.2 Five displacement triggering scenarios outlined by the Human Rights of IDPs adapted from Kälin 2008)

Tier 2: Water-Food Crisis and Human Mobility: Interlinkages, Drivers, Trends, and Patterns

Human mobility is manifested by aggregation of numerous and overlapping direct and indirect drivers. This makes it challenging to define the primary triggers of mobility and influences efforts toward finding appropriate policy solutions. Recent development reports clarify how armed conflicts, violence, human rights violations, unexpected disasters, and increasing frequency and gradient of extreme events are the primary triggers of human displacement or/and migration (the Internal Displacement Monitoring Centre 2018). In most instances, the human mobility episodes feature a water context, mainly water crisis scenarios such as droughts and floods. Hydroclimatic variability, including shifts in seasonal rainfall pattern, increased frequency, and increasing intensity of floods and droughts amplifies the vulnerabilities of populations and communities, often leading to human mobility, whether it is voluntary or forced. The dynamics of human mobility shows maximum flux at the local scale, where scenarios of food and water crisis function. The trends and patterns may differ in different socioecological, sociocultural and sociopolitical settings. Fah (2007) explains how land and water uses, and users and conflicts act as direct or indirect drivers of human mobility. Currently, nearly 25 million people worldwide are displaced due to floods, and other environmental factors and projections estimate in the coming three decades (by 2050) that 200 million people may be exposed to migration as a result of drivers related to a lack of natural resources, and beyond 2050, this number may cross 700 million people. Noting these trends, the interlinkages in water, food, and human security need to be investigated in-depth and through a multidisciplinary perspective.

Human mobility patterns and trends are influenced by land and water interactions in numerous ways depending on the context and settings. Between 1997 and 2011, 4.3–20.2 trillion USD per year worth of ecosystem services were lost due to land-use change (Sukhdev et al. 2009). Also, the development trends such as industrial expansion, agriculture intensification, and myopic water harvesting practices resulted in settings of competing and conflicting demand and supply. This is particularly apparent in the water-stressed regions of the world, further increasing vulnerabilities of communities and populations and augmenting the frequencies of undesired outcomes, including human displacement (Barriopedro et al. 2012). It is estimated that >50% of the world's population now lives in urban areas. Moreover, nearly 30 megacities house >10 million people each (Population Reference Bureau 2018). Population increase exacerbates pressure on limited land and water resources, and these pressures are likely to continue in the coming years. This may lead to undesired consequences for the human capital (Food and Agriculture Organization of the United Nations 2016).

Marchildon et al. (2008) reflect that drought incidence is associated with out-migration in rural Canada, except in places where government relief programs mitigate drought-associated consequences. Between 1900 and 2019, 728 drought events were reported across the world and resulted in enormous burdens for humanity. In total, an estimated 12 million people have been killed; >2.7 billion have been affected, resulting in estimated total economic damages of USD 169 billion. Most deaths by droughts have occurred in Somalia (>20,000 between 2000 and 2017), followed by Malawi, China, and Burundi. One hundred twenty of disasters in Africa, accounting for 40% of Africa's droughts occurred between 2000 and 2017 (Emergency Events Database 2019). In 2010–2011, food prices in Russia, Ukraine, China, and Argentina spiked partly due to droughts and additionally in Canada, Australia, and Brazil due to torrential storms (Mitchell 2014; Dillon et al. 2015). Moreover, due to high variability in food supplies and food prices, the Middle East and north African region were noted as one of the top food importers in the world. Some experts further suggest that the 2011 food price spikes played a role in the Arab Spring (Bren d'Amour et al. 2016; Werrell et al. 2015).

Droughts create diminished water supply, and in long term, persistent droughts or intense floods can limit water and food. Gleick (2014) provides statistics which show how droughts killed >11 million since 1900 and affected >2 billion people worldwide. The famine of Somalia from 2010 to 2012 killed >250, 000 people. Likewise, severe drought and its consequences are linked to state failure in Syria in 2011 (Gleick 2014). The drought period between 2007 and 2011 was the driest period on the instrumental record (Mathbout et al. 2018). As a result of the drought, agricultural production was halved, evident by reductions in wheat production by 47% and barley production by 67%, in addition to livestock populations (Erian 2011). As a result, between 2006 and 2009, an estimated 1.3 million Syrians were impacted by failures of the agriculture sector (Solh 2010). By 2011, the UN estimated this number to have increased to between two and three million, with one million experiencing food insecurity, which in turn precipitated a rural to urban migration of 1.5 million people, comprised mainly of farmers and their families (Kelley et al. 2015). Overall, agriculture is the most affected sector, and farmers bear much of such impacts [=80% of all direct effects, with multiple effects on water availability, agricultural production, food security, and rural livelihoods]. As nearly1.3 billion people rely on agriculture as their primary source of income, drought puts their livelihood at risk, halts and reverses food security and poverty reductions, and will likely hamper the SDG agenda (Food and Agriculture Organization of the United Nations 2019).

South Asia is extremely vulnerable to water and climate extreme events and reports high migration flows. In most cases, vulnerable populations resort to migration as an adaptation strategy. This displacement could be seasonal, temporary, and at times permanent, (Nagabhatla et al. 2014) with the exodus of (climate) refugees in the African subcontinent drought trends shown in Table 4.2 a. Lake Chad, a transboundary water system in Africa, also presents a typical example of land and water resource-related crisis which has led to massive human mobility in past decades. However, such events are often not investigated with human mobility as the primary issue (Nagabhatla and Fioret 2019). The primary source of income in Afghanistan is agriculture which employs about three-quarters of the population. Moreover,

Table 4.2 (**a**)Top ten recorded drought incidents in India and China and (**b**) ten key episodes reflecting total economic damage caused by droughts (data source: Emergency Events Database)

Part a Country	Date	Total number of people affected
India	Jan-2015–Dec-2016	330 million
India	May-1987–Aug-1987	300 million
India	July-2002–2002	300 million
India	1972–1973	200 million
India	1965–1967	100 million
India	Jun-1982–1983	100 million
China	Jan-1994–Dec-1994	82 million
China	Apr-2002–2002	60 million
China	Oct-2009–May-2010	60 million
India	Apr-2000–2001	50 million

Part b Country	Date	Total losses (*1000 US$)
United States of America	Jun-2012–Dec-2012	20 million
China	Jan-1994–Dec-1994	=13.7 million
Mexico	Sep-2011–Dec-2011	8 million
Vietnam	Dec-2015–Feb-2017	6.75 million
Algeria	1981–1983	6 million
Brazil	Jan-2014–Dec-2016	5 million
Spain	Sep-1990–1995	4.5 million
China	Oct-2009–May-2010	3.6 million
Argentina	Jan-2018–Mar-2018	3.4 million
Pakistan	Nov-1999–2003	3.3 million

about 85% of the country's food comes from irrigated farming. The primary industries are also centered on agriculture and pastoral raw materials (the World Bank 2014; Jadin 2018). The drought of 2018, amid protracted conflict, escalated the food crisis, making it the state's worst food insecurity emergency since the 2011 drought (see Fig. 4.3). As a result, the Afghanistan pastureland dried up, prompting distress selling of livestock and a noted increase in animal deaths. Overall, the effect on wheat production (estimated 28% below the 5-year average), combined with inadequate mechanisms to manage food security, escalated the episodes of conflicts. These were further intensified by the limited coping capacities of households and institutions which were depleted by decades of conflict and shrinking foreign aid (Famine Early Warning Systems Network 2019). Integrated Food Security Phase Classification (IPC) analysis in September 2018 estimated that nearly 10 million people (>40% of the rural population) were in a food crisis and emergency and > 2.5 million required urgent action to reduce their food deficits and to protect their livelihoods (Integrated Food Security Phase Classification 2018).

In India, drought-prone districts account for >40% of the agrarian land in the country, which is mostly rainfed lands (68% of net sown area with 48% of it under food crops). The role of the agricultural sector in country's economy is substantial as close to 50% of the rural workforce is concentrated in agrarian regions (National Rainfed Areas Authority, India). The area is highly vulnerable to droughts, which typically occur every 3 years and last for 3–6 years. The impact of droughts on the availability of water for human and livestock and crop and feed production is widely

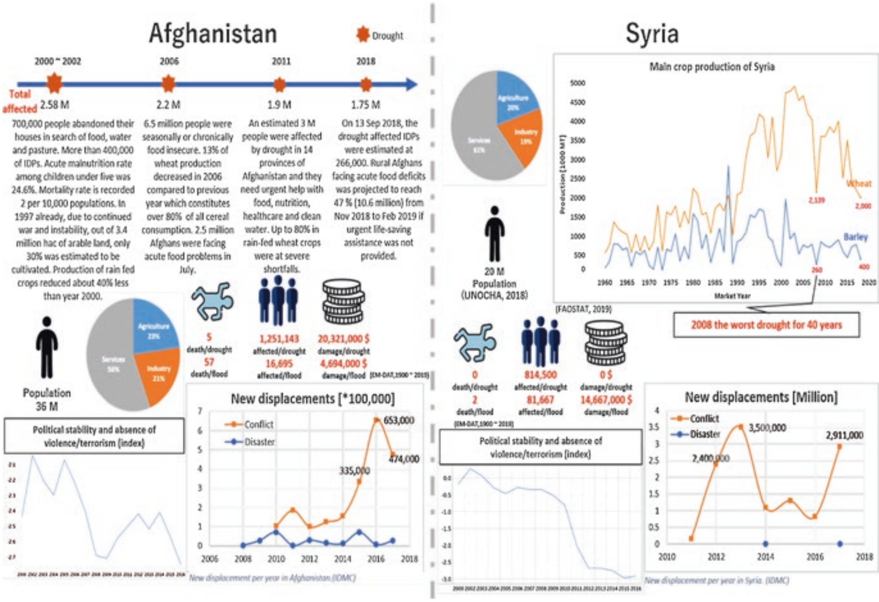

Fig. 4.3 Droughts and their impact on food production, populations, and communities in conflict-ridden geographies, including in scenarios of human mobility and displacement (Data aggregated from various sources: IDMC, FAOSTATS, Emergency Events Database, etc.)

published. However, there is a limited emphasis given to documenting out-migration and other implications of water and food crises. For instance, >75% small- to medium-scale farmers committed suicide in the last decade, of which >75% practiced rainfed agriculture (Mahapatra 2015). Water scarcity in India, with growing physical and economic impacts (costs from source to the field) are no longer a pessimistic projection, but a hard reality, that will bear adverse outcomes such as conflicts (BBC News 2019) and will bear adverse outcomes such as conflicts. This can subsequently lead to the movement of people on a significant scale, likely increase the rural-urban migration pathways.

Increases in water and food demand and insufficient governance structures often force people to migrate. In the case of Syria, food sufficiency policies in the 1960s supported the agrarian sector in managing an increasing annual irrigation demand. However, overexploitation of groundwater, and falling groundwater levels, combined with drought episodes from 2006 to 2011 facilitated vulnerability, conflicts, and the exodus of people moving for survival. This includes up to 1.5 million farmers (and their families) to cities. This was not only destabilizing for the country but further contributed to the most complex geopolitical episode in the last decade – Syria's civil war that started in 2011. Thus, Syria's civil war can also be viewed as a reflection of how local water/agrarian conflicts, alongside a complex collection of social, political, and economic factors, transitioned into significant conflicts and destabilization (Femia and Werrell 2013; Gleick 2014; Kelley et al. 2015).

The projections for China outlined by the IPCC point to an uncertain future if the agricultural benefits promised via technological innovations fail to offset some of the climate change impacts stated Piao et al. (2010). For India, supplemental irrigation of rainfed food production systems can enhance (approximately two- to three-fold) production (yields/hectare) of crops such as wheat, sorghum, and maize for the rainfed system (Swaminathan and Bhavani 2013). Water availability and accessibility remain a crucial factor in human mobility flows, as severe droughts have periodically caused rural-urban migration (Bhagat 2017) and imposed a cumulative loss of nearly seven billion USD (refer Table 4.3). Increasing demographic rates mainly in developing regions is rendering significant pressure on land and water resources. As the per capita water footprint (i.e., the measure of the amount of water required to produce the suite of goods and services consumed by an individual) increases in urban (water provisioning) and rural (agricultural irrigation) settings, the changing trends in land use exacerbates strained land and water resources. For example, a substantial fraction of global grain production is used to feed animals as a result of population shifts to more meat-intensive diets. This, in turn, increases water demands and exerts an upward pressure on global food prices (Liu et al. 2008; Hoekstra and Mekonnen 2012; Brueckner et al. 2017). This loop reveals a case for how cumulative migration triggers stem from water and food crisis settings and may further contribute to economic loss, rural-urban migration flow, local hostilities, inflation, water, and food insecurity.

The human mobility crisis partly influenced by the water and food crisis can have profound impacts as illustrated in Fig. 4.4. The geographical trends and impacts of water and food crisis and human mobility is expanding both for developing and

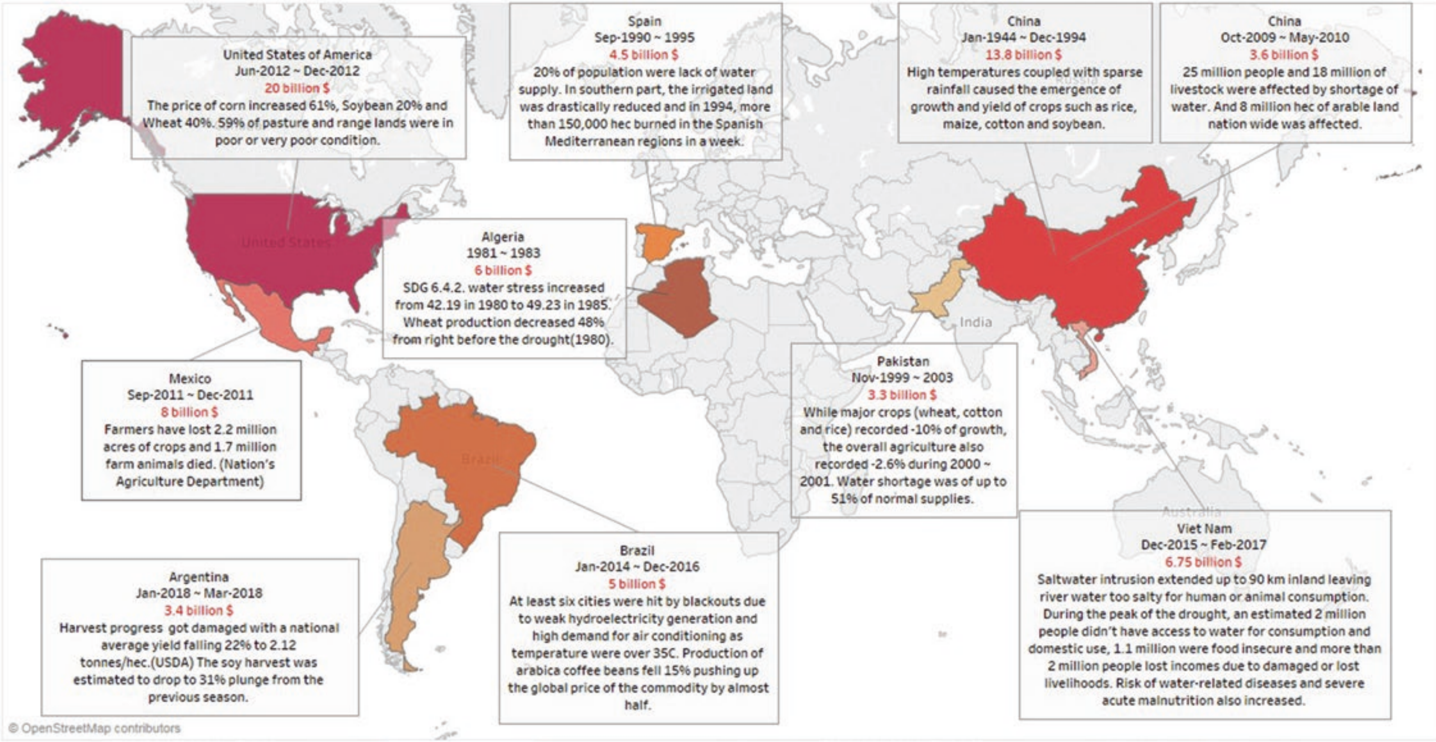

Fig. 4.4 Spatial trends and patterns of water and food crises compiled from various data sources (see reference list) to demonstrate the geographical spread of economic loss, and the presence of food and water insecurity scenarios which eventually trigger human mobility trends and patterns

developed regions. In 2015, the flow of >one million migrants (refugees from Syria, Afghanistan, Iraq, and northern Africa) into Europe precipitated political crises among European Union (EU) member states (BBC 2016). The German government report (May 2017) warned that 6.6 million people might move into Europe from Africa and the Middle East, including refugees from Syria and Iraq and economic migrants from Libya, Niger, Chad, Nigeria, Bangladesh, Guinea, Côte d'Ivoire, and the Gambia. Importantly, these states are also high risk for experiencing water and climate challenges and often food crises. In 2017, the number of displaced people increased to >68.5 million, including >25 million refugees and 40 million IDPs (UNHCR 2018). In 2015, >65 million people were displaced by conflicts, of which more than a quarter was international migrants. The increasing numbers of displaced persons are placing excess pressure on international agencies and on the available resources to respond and effectively manage safe and orderly migration (UNHCR 2015; Bilak et al. 2016). The annual increase in mobility due to natural disasters is notable, accounting for >25 million people since 2006. Populations and communities annually displaced by various environmental disasters are much high compared to people displaced by other types of conflicts. Human mobility driven by slow-onset environmental changes remains difficult to estimate.

Water crises scenarios are increasingly reported as a concern for human development (WWAP 2019). Focusing on the link between water and food crises and human mobility is critical, and our understanding of the trends and patterns are sometimes uncertain. For example, sea-level rises have caused saltwater intrusion onto arable land, flooding has impacted low-lying regions, and the increase in temperature has impacted the productivity of staple food. Oftentimes those impacted have little recourse except to migrate as the only adaptation strategy (the Internal Displacement Monitoring Centre 2018). Flooding can affect water-related infrastructures like pipes and wells, rendering them dysfunctional or damaged and causing interruption of water provisioning systems. This, in turn, increases the number of individuals and communities living in vulnerable situations (i.e., water stress/scarcity).

Globalization, rapid urbanization, climate change, and ecological degradation further trigger internal and international human mobility and IDPs. As of 2015, around 244 million international migrants have been recorded, an increase of 41% since 2000 (United Nations Department of Economic and Social Affairs 2015). Further, in 2017, >30 million IDPs were associated with conflict and disasters across 143 states and territories. The top ten most vulnerable countries, also labeled as “hot spots of conflicts,” account for millions of new displacements. Syria, the Democratic Republic of Congo (DRC), and Iraq jointly accounted for >50% of the total displacement statistics of the year, followed by sub-Saharan Africa and the Middle East, where conflicts sprout from the interplay between resource allocations and resource degradation and act as triggers for human mobility (the Internal Displacement Monitoring Centre 2018).

The interlinkages, trends, and patterns of food and water security and migration illustrate some key points: (a) People move away from water scarcity, including droughts, and aim to reach settlements that are close to water sources. The perception of water availability also coincides with the opinion for economic opportunities. Thus, water acts both as a "push" and "pull" factor. (b) Several socioeconomic and ecological realities of land and water are associated with generating and exacerbating vulnerabilities. These vulnerabilities, in turn, catalyze the push and pull dynamics, leading to undesired outcomes of human mobility. (c) To understand contemporary trends and patterns of human mobility, it is pertinent to look beyond the standard push-pull dynamics, generally derived from conventional migration literature and concepts. (d) Water and food crises are cross-cutting dimensions that directly or indirectly influence human mobility trends and patterns. Understanding these trends and patterns provides an opportunity to create a decision tool for mapping policy options to better manage human mobility.

Mapping Interlinkages in the Water, Food, and Human Mobility Nexus: The Local Perspective

The Congo Basin region illustrates a typical case of the interlinkages in water security, food production, and human mobility in the setting of conflicts (Fig. 4.5). These include hydroclimatic variability, fast-changing water demand-supply dynamics, increasing population, water availability for provisioning and agricultural production, sociocultural complexities that directly and indirectly govern land and water use and users (customary laws vis-à-vis state legislation), civil and political conflicts, some of which are rooted in land and water resources sectors, and increas-

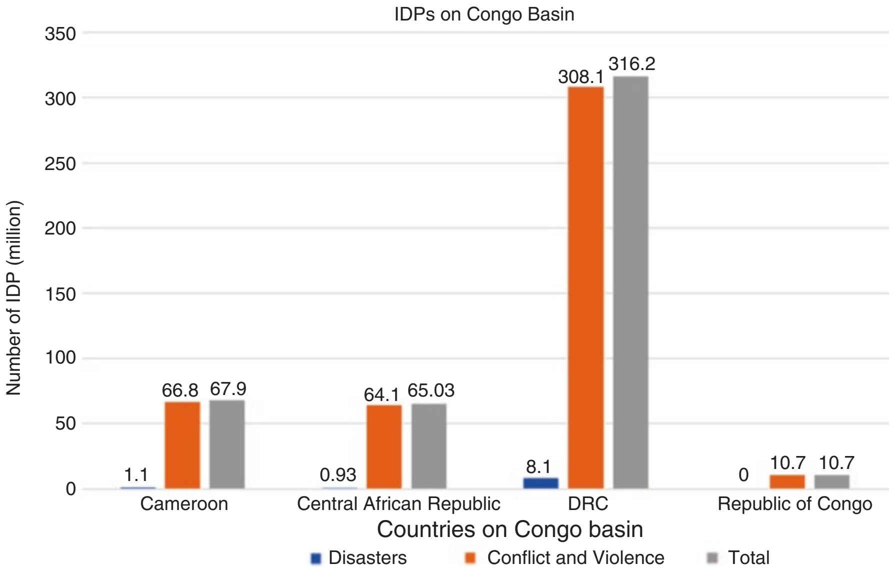

Fig. 4.5 IDPs in the Congo river basin and various triggers as reported by IDMC (2018)

ing episodes of human mobility. Limited data is available on displacement associated with sudden-onset disasters such as floods, etc. The regions exhibit how multifaceted drivers of conflicts are expected to increase pressure on land and water resources and that in turn influences human mobility pathways. Flooding is a significant driver for IDPs pathways in the region, acting along with set of social, ethnic, and political conflicts. During 3 weeks of flooding (December 2015) that severely affected 17 districts of eastern and central Kinshasa, >25 people were reported dead and > hundred thousand displaced. Communities near the Congo River basin and, it's tributary, the N'djili overflowed, forcing people to flee their homes or forced face displacement. Individual and community assets such as churches, schools, and other infrastructure were loss. Flooding left many without drinking water as the "Regideso" water treatment plant was affected (BBC News 2015).

In 2017, the DRC had recorded the second-highest level of new displacements globally due to conflict and the third-highest overall levels of migration. North and South Kivu provinces noted the highest number of IDPs, who were displaced as a result of inter-communal clashes, conflicts, and natural disasters, among other reasons. Furthermore, Tanganyika, Kasai, Kasai-Oriental, and Ituri experienced a local collapse of their economies due to the high flow of internal displacement sequentially destruction of fields, food, and markets and drop-in school attendance (Internal Displacement Monitoring Centre 2018).

A recent study estimates that >13 million people in DRC need assistance, including >600,000 international migrants and > 4.5 million IDPs (Schlindwein n.d.), the news interface (DW) reports that, "*since the start of 2018, more than 50,000 Congolese have fled to Uganda, many by boat through Lake Albert which borders between east DRC) and Uganda. Each day >500 people reach to Uganda side of the lake. Escaping across the water is dangerous…*" UNDP assessment of the region underlines the impact that sea-level rise and land degradation have had in driving large-scale mobility (Goeman 2019). The number of food-insecure people has doubled from 7.7 million (2017) to >13 million (2018). Access to food is a daily struggle for a significant part of the Congolese population, and consequently, >five million children are acutely malnourished, placing the DRC as having the second-largest hunger crisis in the world after Yemen. The 2016 Cost of Hunger in Africa study found that under nutrition cost, the DRC close to 5% it's Gross Domestic Product (GDP), i.e., US$ 1.7 billion/annum (World Food Programme 2019).

The case of DRC emphasizes the relevance of integrating ecological and socio-economic complexities. The country's troubled legacy of conflict, environmental degradation, rapid urbanization, and underinvestment in land and water management has severely affected water and food provisioning and influenced mass mobility patterns. There is a need for projects, programs, and investments that support participatory approaches to tackling water and food crisis, conflict resolution, and challenges related to growing trends of human mobility in the region. In this context, a new initiative funded by International Development Research Center (IDRC, Canada) for the Congo region/basin that is in the area co-coordinated by UNU INWEH (https://inweh.unu.edu/project-launch-addressing-climate-and-water-driven-migration-and-conflict-interlinkages-to-build-community-resilience-in-the-congo-basin/) focuses on building community resilience as an adaptation strategy, mitigating conflicts generated through the different use of land and water resources, and water generation of enhanced understanding crisis-driven migration can assist in filling existing gaps and needs.

Discussion Points

Multiple factors drive water and food crises and affect various facets of human and sustainable development. Droughts, floods, sea-level rise, salt-water intrusion, water quality issues, poor access due to inadequate water infrastructure, or/and poor water management practices, directly and indirectly, influence human mobility and displacement. It remains challenging to isolate the role of specific or isolated contributors, for example, how change in rainfall variability, disaster/climate change impacts, or water quality affects the decision of people to migrate. The complexity in understanding these interlinkages is a constraint for migration policy discussions to be inclusive and integrated. Better management of land and water resources and managing challenges related to competing uses can serve as a preemptive strategy to manage conflicts related to natural resources that, in turn, triggers migration and negatively impacts vulnerable communities. The suggested three-tiered approach presents a scalable framework to examine how food and water crisis influences human mobility in various settings.

Analysis of narratives, trends, and patterns provides a comprehensive approach to investigate the relatively under-investigated influencers of human mobility, viz., conflicts, peace, and health, existing within the water and food crisis scenarios. Multiple droughts and floods in large grain-exporting countries in 2010 reduced food production and triggered the increase in global food prices. In Syria, for example, drought exacerbated the problems posed due to constant high water demand and poor agricultural policies (Gleick and Iceland 2018). It is vital to ensure that water and food crisis scenarios do not transition into a critical humanitarian crisis, as in the case of the Syrian Conflict (Gleick 2014).

These drivers of human mobility do not operate in a linear order; they act in tandem and include a variety of situational and contextual conditions. Among others, this includes sociopolitical settings, poverty and inequality, fragility, poor governance, and humanitarian crisis. The decisions around human mobility are also influenced by the overall socioeconomic contexts (Afsar 2003). The poor are the most vulnerable and have limited choice, skills, or economic ability. Comprehensive studies that tie human mobility with food and water crisis are currently limited or nonexistent. Present evidence assumes that climate change leads a linear pattern of human mobility (Kniveton et al. 2008), an argument often challenged by migration experts. The aggregated account of trends and patterns presented in the chapter provides for an enhanced understanding of the interplay of direct and indirect drivers of human mobility and calls for proper risk assessment of migration scenarios resulting from various aspects of water and food crisis.

Different "narratives" of migration are relevant for contextualizing human mobility within the food-water-crisis nexus. These narratives comment on the significance of assimilating climate, ecological, and socioeconomic interlinkages and emphasize the role of "problem framing." A focus on framing the problem can, in turn, facilitate negotiation and mediation and consensus-building for managing spillover impacts of unplanned human mobility and help maintain human security. Managing the unintended outcomes of human mobility, voluntary or forced, internal or international, exhibited within water-food crisis scenarios needs to be tackled in tandem with overall migration assessment and policy discourse and likely within the global sustainability agenda. The new and emerging human mobility trends and patterns should be appropriately assessed to outline a collective and integrated approach for strengthening the adaptive capacity for individuals and populations living in vulnerable situations (Niva et al. 2019). Also, it is essential to note the need to improve the sustainability, so that migration as an adaptation method does not create a situation where migrants move from one vulnerability to another (Niva et al. 2019). A lack of engagement mechanisms and participatory approaches to tackle crises related to resource systems can also lead to massive conflicts and the disruption of political stability and thereby pose a threat to human security (Jägerskog et al. 2015).

Another important dimension human mobility stemming from water and food crises does not meet the legal requirements for migrants to be considered as "refugees" (i.e., those forced to migrate as the result of conflict or persecution and a lack of state protection). This emphasizes the need to widen the scope of existing migration policies. Moreover, the distinction between forced displacement and voluntary movement is rarely clear. The complex debate on the term "refugee" or "climate refugee," used to describe forced displacement by environmental changes, reflects the contrast in perceptions. While environmental scientists favor the terminology, migration theorists don't (Piguet 2013). Besides the conundrum of conceptual framing, the challenge of isolating clear drivers of human mobility also applies (Foresight 2011). Census data on tracking human mobility rarely includes drivers related to water, land, food, or climate settings. Instead, attribution to one or other proximal causes, such as loss of livelihood, is prevalent (Upadhyay et al. 2015). The linguistics of addressing water, food, and climate crisis-driven human mobility remains constricted and fuzzy. While IDPs are protected under the 1998 Guiding Principles on Internal Displacement, the international migration laws provide no clear status for people and communities dealing with extreme vulnerabilities. The United Nations High Commissioner on Refugees (UNHCR) agenda on recognizing human displacement in response to climate change encouraged states to acknowledge and offer protection to those displaced by environmental changes (McAdam 2013). The post-2015 SDG agenda could also serve to steer better efforts to map, address, and tackle the food-water-human mobility nexus.

Empirical clarity and up-to-date data, information, and knowledge remain crucial evidence to support policy outcomes in the interlinked and complex water and food crisis scenarios. Integrated assessment can provide for a clear way to generate evidence and subsequently frameworks for a decision support system. For instance, SDG16.8 calls for "*strengthening the participation of developing countries in the institutions of global governance can also benefit from the availability of knowledgeable…*" And, SDG 16.10 and 16.b emphasizes the provision of quantitative information to advance the scope of international agreements and the promotion of laws and policies for sustainable development. Noting that human mobility concerns are a global development challenge, better understanding of this nexus can help transform empirical synthesis into actual evidence for better policy outcomes.

Migration and environment are policy realms which are generating high levels of concern in current times, both politically and among the public. But developing strategies to integrate these issues in the development agenda remains challenging, both domestically and internationally (Foresight 2011). The international community is becoming more aware of intensifying human mobility patterns. However, there has been little success in developing supporting policies and programs to accommodate and address multi-scalar (local, across borders) and multifaceted (seasonal, temporary, permanent, internal) aspects of human mobility. To some extent, the specifics applicable to water and food crisis-related human mobility get shaded by the host country in the general framings of immigration and security policies (Aiken et al. 2014). Integrated policy frameworks to support and protect migrants are only a part of that planning. Designing long-term solution to address water and food needs of individuals and populations living in vulnerable situations is further needed (Long and Rosengaertner 2016).

Concluding Notes

Water and food crises aggravate pressure on land and water resources due to competing and conflicting uses. This often leads to conflicts which in turn can trigger mobility, influence socioeconomic and sociocultural settings, intensify inequality and poverty, and inhibit human development. This hypothesis loop is described in the chapter by outlining a three-tiered approach. Two key points emerge from the synthesis: (a) Lack of water security undermines the lives and livelihoods of people, and food and water provisions and other basic needs bear a close link with human mobility trends and patterns. And, (b) water and food crisis driving human mobility operates in tandem with different social, political, economic, and demographic drivers. Improving the coordination apparatus of human mobility by providing a schematic way to address complexity and interdisciplinarity inherent to the food-water crisis-human mobility nexus. Apart from economic and financial burdens, unplanned human mobility, in general, affects the well-being of people, communities, and states' loss of habitation, as well as social and cultural identities. The global agenda to address this phenomenon would need well-deliberated and inclusive policy actions toward the resolution of conflicts and steering sustainability. That said, in-depth investigation of changing trends in water and food crisis and resulting patterns of human mobility is needed to achieve integrated assessments and effective management of precarious and irregular human mobility pathways.

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Annexure

Aggregation of multiple narratives as a tool to explain pluralistic dimensions and interlinkages that apply to land, food, and water crisis settings and resulting human mobility

Narrative and related information	Explanation, example, and context
The theoretical narrative Identifies environmental (climate and ecological degradation related events)-driven human mobility migration as a central component to migration assessment discourse and planning An in-depth focus on direct and indirect drivers remain limited The rate and severity of environmental changes are rapidly increasing, and consequently, so are the number of people affected, empirical evidence is generic and often scattered	Environmental change is unquestionably the most significant influence on patterns of migration worldwide (Hynie et al. 2016) Estimates and projections by various agencies helps to provide evidence. For example, Brown (2007) estimates that 200 million people may be displaced by environmental changes by 2050 The spectrum of direct and indirect environmental drivers escalates and exacerbates other drivers of migration, such as conflict and dwindling livelihood opportunities. Focus on understanding interlinkages is pertinent
The narrative of "duality" Is an overarching aspect of human mobility Migration gives rise to both opportunities and challenges in the areas of origin and destination In cases, mainly where agriculture is characterized by underemployment, migration may result in better employment opportunities and higher incomes for those who remain	At the place of destination, when migrants are socially and economically integrated into the host communities, they may contribute to GDP and innovation and skillset upgrade (FAO 2018) Migration from rural areas could have negative implications for agricultural productivity due to labor shortages, affect intra-household labor substitution patterns, and add to the work burden of women

(continued)

Narrative and related information	Explanation, example, and context
The historical narrative Claims that human mobility connects with water in many sociocultural and socioeconomic settings Despite these early historical insights, references to the environment (climate, water, extreme events) as a prominent factor disappeared progressively from the migration literature over the twentieth century In 1889, poor climate conditions precipitated currents of migration that also persist today In the 1980s and early 1990s, a few landmark publications raised the issue and shared alarmist estimates of the people foreseen to move (Piguet et al. 2011)	Human mobility is seen as a common adaptation strategy (Afsar 2003) Nomads and pastoralists in Africa, Middle East, and Asia, in particular, carved customary migration pathways to ensure water and food for their livestock Migration known to provide sustained livelihood and provisioning for their communities (Jägerskog et al. 2016)
The human development narrative Is a firmly entangled with the water-food crisis and human mobility nexus Water demand has increased in many regions of the world in order to meet the food and energy demands of the growing population As such, water represents a critical development factor in economic growth-oriented development models This narrative is more significant if governance is weak, infrastructure inadequate, and institutions fragile (Gleick and Iceland 2018)	Increasing pressure on water resources undermines water security and contributing to conflict, migration, and food insecurity in many parts of the world Currently, crisis scenarios relating to water availability and accessibility increase the severity of drought and flood events, biodiversity-watersheds-ecosystems degradation, challenges in managing wastewater (municipal, industrial, and agricultural), and dynamics of surface water and groundwater use
The socioeconomic and gender narrative Is apparent yet often overlooked dimension Unstable living conditions that manifest in human mobility scenarios are not usually sensitive to gender norms In Africa, where most IDPs stay with relatives or in host communities, hosts in turn may exhaust their resources in addressing the new arrivals (IDMC 2012) or the gender groups can be subjected to harassments and assault	Women are generally vulnerable, particularly with respect to gender-based violence, as are children (Internal Displacement Monitoring Centre (IDMC 2019) Unplanned human mobility poses a potential threat to human security and sustainability, particularly through the loss of productive land, livestock, home, and vital assets as a result of water and food crises (IDMC 2018) IDPs often lose land, property, livelihoods, and access to health services and education and therein become poor
The climate change narrative Is multifaceted, and its impact on human mobility is embedded at various levels in the emerging pathways of human mobility In 1990, the first UN IPCC report on climate change raised the alarm that the gravest effect of climate change may be on human migrants as millions will be displaced (IPCC 1992)	Impacts of climate change reduce the communities' resilience to cope with shocks (i.e., environmental, social, and political). For example, infrastructure damage (e.g., broken water pipes, contaminated water) caused from flooding increases the exposure of communities and populations to risks such as waterborne diseases and malnutrition and thereby creates a situation of acute food and water insecurity (IDMC 2018)

(continued)

Narrative and related information	Explanation, example, and context
The narrative of adaptation Argues that migration represents an unsustainable adaptation pathway which reflect a mismatch between expectations and reality Migrants who move to seek better employment opportunities may move from one vulnerability to another (Black et al. 2011) Also, applies to the rural to urban mobility	IPCC states, "*migration is the only option in response to sea-level rise that inundates islands and coastal settlement*" (IPCC 2007) indicating that some cases of relocation occur in low-resource settings, where migration is the only option for survival The internal displacement of people and communities in Africa and Asia has been associated with the occurrence of droughts. However, limited information is available as to how floods, droughts, climate extreme events, and food and climate crisis triggers international and long-distance migration. The cost burden of internal displacement and international migration can be quite different, and frequently people may choose to spend their money on food and survival needs instead of the cost of moving far away (international migration)
The narrative of environmental determinism States that environmental changes tend to affect individuals and communities differently. Vulnerability theories emphasize that the impact of any specific environmental change depends on the affected individuals' and communities' ability to adapt (McLeman and Smit 2006) It remains challenging to attribute specific environmental conditions as a main cause of human mobility trends and patterns, particularly at the local scale (Black et al. 2011)	The individual and community capabilities and nation and state level abilities to cope with migration induced through environmental change are intertwined with existing institutional and polices measure that states have in place, such as insurances for crop failure due to extreme events or compensation policies for loss of income, etc. Subjective assessments may overlook the intricacies governing this nexus. For example, when reporting the reasons behind migration, those experiencing water and food crisis can perceive more proximal drivers, such as livelihoods, as the primary deciding factor Existing climate adaptation strategies and development plans for managing detrimental effects of environmental change, resilience building, land, and water management usually do not factor addressing the resultant human mobility
The narratives of health, tenure rights, ownerships, and allocations These factors influence displacement of people, as safe and accessible water is fundamental to human development and well-being (e.g., human consumption, domestic use, food production, or recreation) Development projects like dam construction or irrigation system expansion lead to the redistribution of water allotments among sharing stakeholders (Gleick 2000)	Making a distinction between territory and property is essential when considering water management planning options. Territory implies stewardship of nature and its resources (including water), whereas "property" refers to something that can be cordoned-off and privatized Human mobility driven from centralized ownership can be addressed by instituting a system of collective ownership for water

(continued)

Narrative and related information	Explanation, example, and context
The narrative of conflicts Future projections show that nations and states may face extreme water stress in the case of heavy dependency on river water which is controlled by upstream nations who have unresolved water-sharing issues Water crisis is becoming acute, and conflicts in shared water basins are on the rise (OECD 2012; DNI 2012) Conflicts negatively influence community's resilience to cope with the impacts of climate change	Water and food crisis-induced human mobility, in some cases, links to conflict and violence Conflicts are further connected to situations when population and communities are directly affected by food and water crisis. For example, high rainfall variability intensifies competing use of land and water resources and augments pre-existing disputes or other drivers of human mobility, thereby indirectly aggravating mobility (IDMC 2018) Conflicts also increase the risks of displacement
The narrative of SDGs Solomon and Sheldon (2018) explain that the declaration accompanying the adoption of the SDGs, recognizes the positive contribution of migrants for "inclusive growth and sustainable development" World Water Development Report of 2019 and World Water Day theme of 2019 "leaving no one behind" presents a narrative of inclusivity (WWAP 2019)	It is widely argued that human mobility and displacement context are underrepresented in the sustainable development agenda (Samman et al. 2018) Increasingly, the member states of United Nations are acknowledging that "international migration" is a multidimensional reality of significant relevance for the development of countries of origin, transit, and destination and requires coherent and comprehensive responses

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Part II
Climate Variability and Food Security

The four chapters in this part zero-in on specific regions and assess the threats, impacts, and likely outcomes for the land, the water, the biodiversity, and the human population.

Squires and Gaur begin with the assertion that smallholders are the key to providing "survival" food security. The critical role of smallholders is explained. Over half of all the food that is produced is from the efforts of smallholders who are to be credited with feeding their own households and generating a surplus for sale. There is focus on *essential food for a reasonably healthy life*, i.e., on basic food security being the *provision of essential food for survival*. One of the agricultural pathways toward sustainable food and nutrition security is through local production of nutritious food, an activity in which smallholders play a crucial role. As food consumers, all rural and urban people in developing countries count heavily on the efficiency of their local smallholders to satisfy their food needs.

Problems of a different kind (mainly natural disasters) are at the core of the chapter relating to the western Balkan region (*Augustyn, van t'Wout and Terzic*). Agricultural risk reduction plays a key role in maintaining viable livelihoods in the ever-changing world. Climate change as manifested in a higher frequency (and severity) of extreme weather events as well as the slower, but seemingly unstoppable, climate shifts impacts agricultural production, especially cropping.

All aspects of food security are potentially affected by climate change, including food access, utilization, and price stability, and these impacts are explained.

From Cameroon there is a case study (*Tume et al.*) that analyzes the impacts and expected outcomes for people in the highlands. The information presented helps us to understand the plight of the poverty-stricken mountain dwellers and the various ways that climate change will affect their lives and livelihoods over the coming decades.

Food security in China, as the most populous nation on earth, is of primary concern, and the multifaceted and multidimensional nature of ensuring enough food and guaranteeing its safety has been dealt with here (*Squires and Feng*). Attention has been paid to the major transitions in agriculture over the past few decades.

Chapter 5
The Critical Role of Smallholders in Ensuring Food Security

Victor R. Squires, Mahesh K. Gaur, and Haiying Feng

Preamble

There is no consensus or universal definition of the term **smallholder** (Bosc et al. 2013). The term is commonly used to refer to farms less than 2 ha in size.[1] Other authors do not define smallholder farm systems by land area but instead base their definition on other identifiers. Some such identifiers include reliance on family labor, percentage of production consumed on-farm, and quantity of economic output. Smallholder farms can also be distinguished from other farms by the economic size of their farm, a measure derived by scaling farm area by the revenue produced per unit of land, the cost of renting or selling land, or the amount of income derived from an area of land. Economic size can substantially diverge from physical size. We interpret agriculture broadly, to incorporate crops and livestock, but also agroforestry, fisheries, aquaculture, hunting, and resource extraction, which frequently form part of diversified smallholder livelihoods

Much has been written about food security. Several different elements are identified in the most widely accepted definitions (Fig. 5.1).

[1] The term "smallholders" is widely understood to include small farmers who do not own or control the land they farm. In some cases they may have a formal use right. See FAO for a discourse on smallholders and their characteristics. http://www.fao.org/docrep/t0211e/T0211E03.htm

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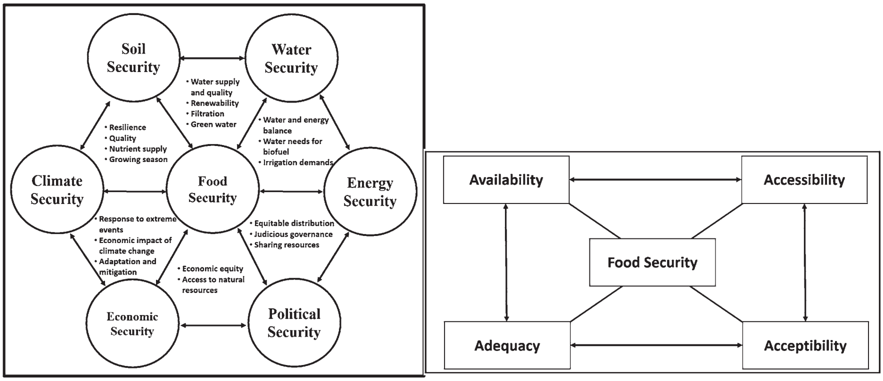


Fig. 5.1 a, b Food security is a multifaceted and multidimensional concept as shown here. Availability Access, Adequacy, Acceptability are key elements in many definitions

But in this chapter we will focus, as our central theme, on basic food security being the "provision of essential food for survival." We are talking about *essential food for a reasonably healthy life*. The defining characteristic of very low food security is that, at times during the year, the food intake of household members is reduced and their normal eating patterns are disrupted because the household lacks money and other resources for food. Food security, following FAO definition and concepts, is achieved when individuals have the food they need to live their lives: it depends on sufficient, adequate food being available; people having access to it; food being well utilized; and on reliable availability and access. Adequate nutrition depends partly on access to food but also on the health environment and level of child care. Undernutrition and "hidden hunger" may well be part of the seasonal variation in food supply and quality. One billion peoples – half of which are small farmers – are hungry. Globally, food security is said to exist for about 4.7 billion persons with another two billion being food insecure in terms of substandard diets and vitamin and micronutrient deficiencies that impair physical and intellectual capacity. Figure 5.2 illustrates the problem using WHO data from Zambia.

To protect the basic nutrition of the most vulnerable and improve food security, social protection and nutrition actions are needed.

If global population stabilizes at around nine billion by 2050 as optimistically predicted, food demands will rise to an equivalent of 12 billion of today's persons due to such factors as affluence-induced food preferences and food wastage in urban supply chains (Braun 2009). And these population projections now look overly optimistic. The vision for food security for all is not achievable from current institutional approaches. No credible prediction of future technologies and policies for food security exists: nevertheless, we may be reasonably sure that a 2050 population of nine billion, mainly in cities, could not be supported from current approaches to food production. With more people now living in cities than rural areas, costs of supplying food (and the extent of food wastage) rise and spawn a new risk, the hungry urban poor. This group can riot and threaten security – hence food security becomes a national security matter (see below). This explains the instructive cases of China and India placing a high priority for food security. Investments such as

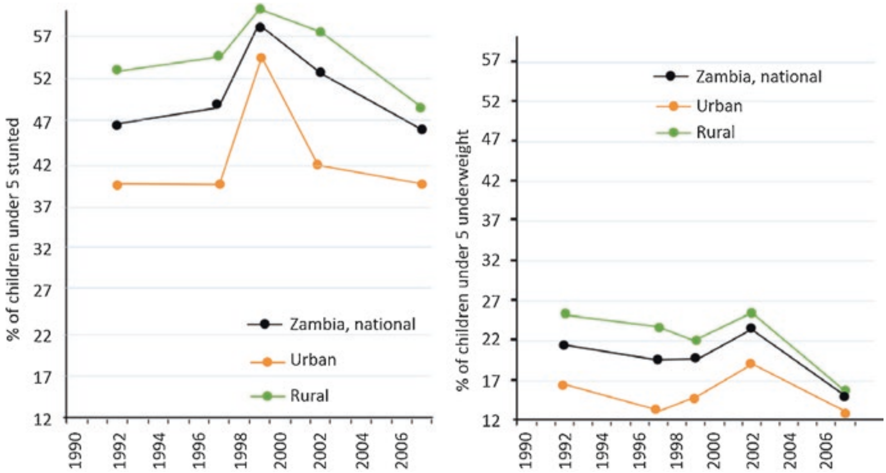


Fig. 5.2 Stunting [A] and underweight[B] children under five, moderate and severe 1992–2012, Zambia. (Source: With data from WHO Global database on Child Growth and Malnutrition)

rural access (infrastructure like roads, railways) and agricultural research have allowed China to feed itself in the face of various predictions to the contrary. Today China is a leader in both farming new and foreign lands (Squires 2018) and in agricultural research, as well as being the world's largest food producer. India has also fed herself but through a different approach based on subsidies of over $25 billion per annum for fertilizer as well as other subsidies for power, water, and food prices and by a priority on domestic stability before export. Both countries intervened in favor of food security by managing emerging risks, such as rising demand for water use efficiency. India's response is through water user's associations, participatory watershed schemes, and community-based rain harvesting, while China relies on incentives for irrigation systems managers. Gulati and Fan (2008) note that both countries accept food self-sufficiency as the key to food security, with liberalized market approaches restricted to surplus-to-security food. Other countries are less organized, and outcomes of this neglect are food shortages in urban areas. The urban poor are no longer just another urban issue but are fast becoming a serious problem.

Social Stability Depends on Food Security

Neglect of a proper food security policy can be a source of civil unrest (Braun 2009). In the past hungry peasants walked in search of food or starved, whereas today hungry urban dwellers readily coalesce into mobs seeking targets on which to vent their anger. Governments' first priority is to forestall such civil unrest. Rising incidence of food protests in more than 60 countries since 2007, of which more than half were violent, seems to follow spiralling grain prices. As the conflict in

Syria has unfolded, experts increasingly point to the nation's drought as a significant underlying factor in the conflict. From 2006 to 2011, severe drought affected over 60% of the land and destroyed the livelihoods of many Syrian farmers. Crop failures of 75–100% were common. By 2010 some one million Syrian farmers were forced into cities already crowded with refugees from Iraq. Observers caution that other nations could experience similar challenges. A study from NASA's Goddard Space Flight Center projected that the Middle East, North Africa, Pakistan, and other desert regions will likely see increased periods without rain as global temperatures increase. As devastating droughts destroy agricultural livelihoods and send farmers fleeing to cities, the world risks repeating crises like that in Syria.

History informs us that most cities arose in fertile valleys and deltas close to their food supplies. Continued expansion of cities has produced the almost unbelievable situation where the area of the combined cities of the world covering the best farmland is the equivalent of half the area of China. Good food policy allows both small and large farmers to innovate. The world needs all the food that it can produce. Added to the increased food demand is that of changing dietary habits. The so-called affluent diets seem to have only minimal effect so far but retain the potential to skew demand as they have done in urban areas of China (Squires et al. 2015). It is projected that at current levels of crop yields, increases in land and water requirements for affluent diets could rise in East Asia by 47–70% and in South Asia by 30–57%. Of course, such additional resources do not exist. That is why increased yields and efficiency in water delivery and on-farm use are imperative. Hence, China's emphasis on food grain production in the face of other market demands, and its apparent willingness to move toward treating non-essential foods under an open policy trade.

More critical to food security, since it is affected by both climate and urban competition, is water. Grain is produced under mainly rainfed conditions, as in the five major global exporters. But the success of Asia to feed itself and export surplus relies on irrigation. This means that the largest food production area in the world is faced with increased competition for water from the most populous cities of the world. Quarantining water for food production will require strong governance. Such variables as these have never before been faced simultaneously. It is one thing to say that "the challenge is great," but that tends to lead to more of the same interventions as in the past.

Now that food security has become a primary focus for many governments of food-marginal countries, multiple strategies will become essential, including food reserves. As Falvey (2010) reminds us, food reserves around the world have been allowed to decline over recent decades. This has been done in a managed way in China as a cost-saving measure. At the same time, China has increased yields, production, and cultivated area by huge research investments and political might and investment. Smaller nations cannot do this, and neither do they have China's diversity of environments. Hence they will need to consider reestablishing and maintaining reserves. It must be remembered that in many Asian, African, and Latin American countries the vast majority of food is consumed in its country of production. Figure 5.3 shows the ratio of rice produced and proportion for local consumption as well as the level of self-sufficiency. It is significant that many of ASEAN countries depend on smallholders to produce food for their populous and for export.

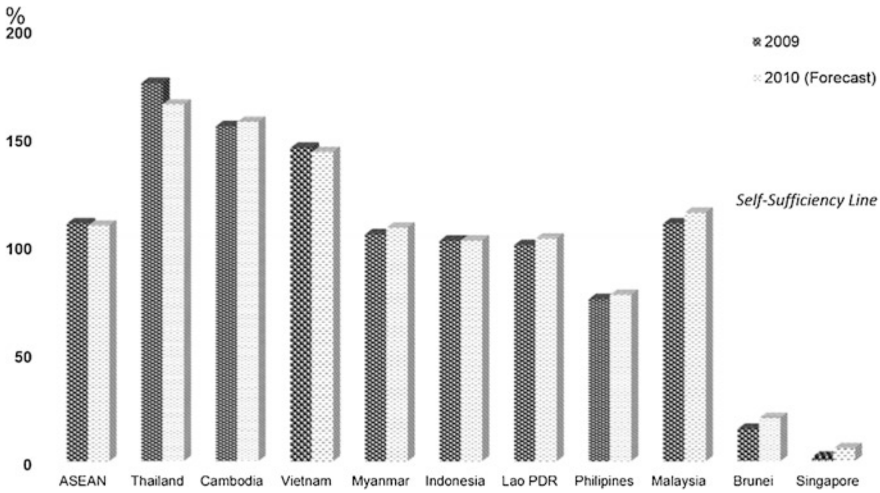


Fig. 5.3 Ratio of rice produced to local consumption in selected ASEAN countries

Smallholders Play a Vital Role in Ensuring the Basic Level of Food Security

In reality smallholders, especially small farmers, feed the world. IFAD and FAO put the number of small farmers at about 530 million (85% of all farms across the world). These are supported by two billion persons – about one third of the world's population – most whom are feeding themselves, some of them produce a surplus (Samberg et al. 2016). Smallholder farmers are also estimated to represent half of the hungry worldwide and probably three-quarters of the hungry in Africa (Sanchez and Swaminathan 2005). Consequently, the fate of smallholder farmers will largely determine whether or not the world succeeds in reducing poverty and hunger worldwide and meeting the Millennium Development Goals. Of the world's 530 million farms, FAO records 85% as less than 2 hectares (ha), 12% between 2 and 10 ha, 2.7% between 10 and 100 ha, and only 0.6% of more than 100 ha (Samberg et al. 2016). The small farm sector of poor countries involves some two billion people – it feeds them and provides surplus for non-producers in towns and cities. Most small farmers live in poor countries (where most of the world's population live anyway). Smallholders have a significant role to play in the world food production system and in the overall economy (Fig. 5.4).

India and China with their huge and diverse populations have large numbers of smallholders. Some live in the drier agropastoral zones and even in the deserts; but most are tilling pocket handkerchief-sized farms and feeding their families. Some are landless (see below). The average farm size in most poor countries continues to decline (Figs. 5.5 and 5.6).

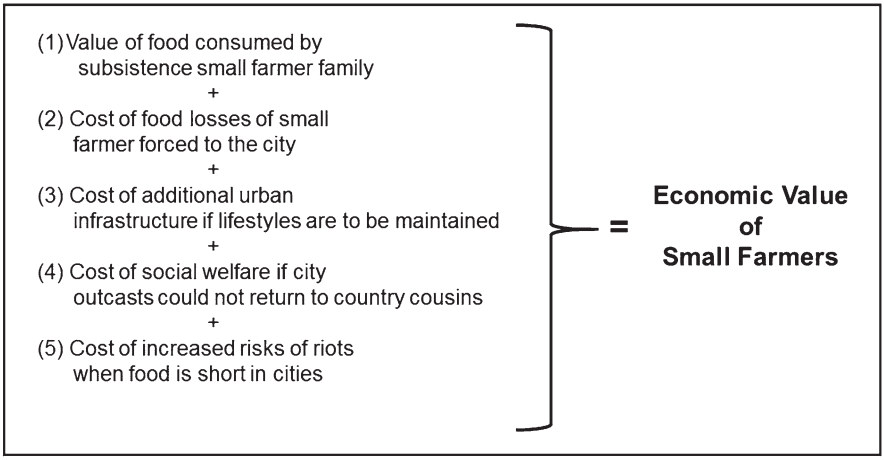


Fig. 5.4 The economic value of smallholders must take into account five distinct roles

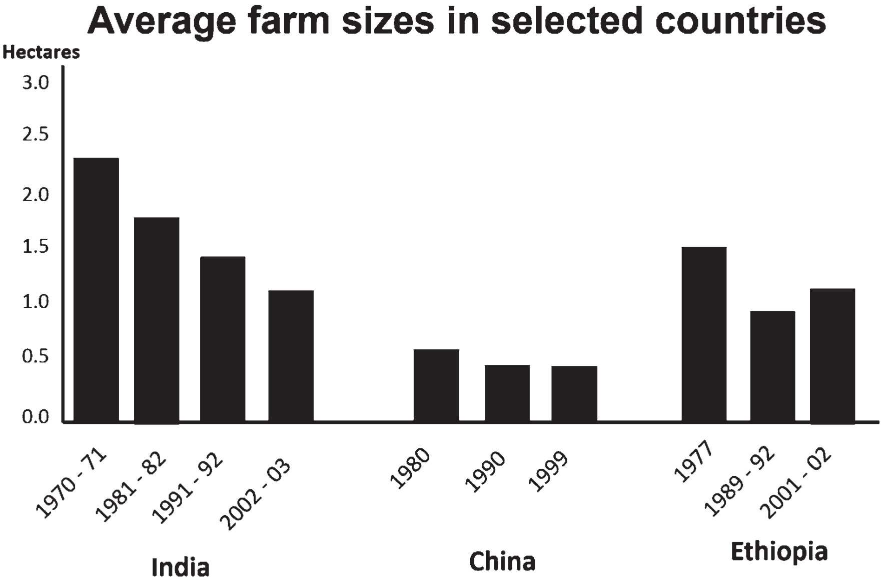


Fig. 5.5 Average farm size has fallen dramatically in India and Ethiopia, largely in response to population pressure. China started off from a low base and is constrained in further subdivision. Part of the decline is attributed to land lost by urbanization and infrastructure development

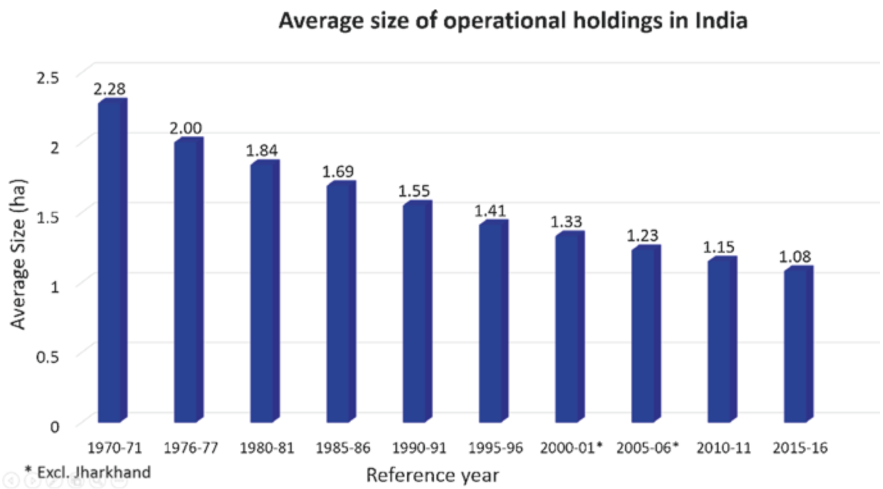


Fig. 5.6 Trends in farm size per household in India since the census of 1970–1971

China has the remarkable distinction of feeding its huge population from the smallest area of arable land per capita in the world. Farm size in China was trending downward, but of late there has been policy reform away from small individual plots under the household contract responsibility system[2] introduced in the 1980s. Land consolidation, usually as result of the pooling of land and water resources within farmer cooperatives, has seen a statistically significant rise in the reported farm size. In India, for example, farm size has fallen from 1.41 ha to 1.08 ha in the past 20 years (Fig. 5.4). As much as 67% of India's farmland is held by the marginal farmers with holdings below 1 hectare. The average size of the holding has been estimated as 1.15 hectare. The average size of these holdings has shown a steady declining trend over various agriculture censuses since 1970–1971.

A similar trend in reduced size of farms has occurred in Ethiopia. Few countries in the world are more synonymous with starvation and famine than Ethiopia. The Ethiopian highlands are highly agrarian and densely populated relative to its fragile natural resource base. Farm sizes are generally very small in the Ethiopian highlands (Fig. 5.6) and declining over time (Headey et al. 2014). The average farm size varies with the agroecological region. For example, the average is 0.49 ha in the Southern Nations, Nationalities, and Peoples' (SNNP) Region where the percentage of farmers with less than 0.5 ha is highest (61.7%) to Oromia and Tigray where farm size is near 1 ha and the percentage of farms with less than 0.5 ha is less than 30%.

[2] HCRS Since the mid-1980s under this policy, all livestock and rangeland resources (except the land itself) that originally belonged to the State and were used communally in collectives were distributed to each householder according to family size, at that time. There was a contract between the government and the householder to produce a quota of produce. Surplus, above the quota, would accrue to the householder. It provided incentive to produce, whereas before there was none.

Fig. 5.7 Frequency distribution of average area of cultivated land per holder in the Ethiopian highlands. More than 57% of holders have <0.5 ha. (Source: Headey Dereje and Taffesse, 2014)

Nationally, average farm sizes declined from an estimated 1.4 ha per holding in the 1977 agricultural census to just below 1.0 ha in recent times. Farmers below the age of 38 have farm sizes that are almost 0.2 ha smaller than farmers aged 50 years and about 0.3 hectare smaller than those aged 60 years. Young rural households face particularly severe land constraints (Fig. 5.7).

India has many people, little arable land, and burgeoning populations, so a brief analysis of what the situation is in India could be very instructive. India has made great strides since independence, but there are a few major reasons which still keep it among the league of developing nation. These are teeming population, over-dependency of rural population (about 70%) on agriculture, fragmentation of land holdings, decreasing growth in agricultural production due to depleting natural resources (particularly land productivity and water resources), and weak implementation of various developmental programs aimed to promote sustainable development. Food security is the major issue among all these problems, as it impedes the development of the people as well as the country.

Problems of Food Production

Small and fragmented land holdings, land degradation (due to soil and water erosion) resulting in depletion of land productivity, improper use of water resources, old-fashioned agricultural production technologies, and absence of required infrastructure for postharvest management and marketing of agriculture produce are responsible for lower yield and income of farmers.

The Indian Green Revolution worked very well particularly in Punjab, Haryana, and parts of Uttar Pradesh and parts of Rajasthan, where lands were well developed and fertile, water for irrigation was readily available, and farmers were keen to increase their farm productivity and income. Generous support was extended by the government to develop the necessary infrastructure for individual farmers as well as for building common infrastructural facilities. As a result, the area under crop production increased from 115.58 Mha in 1960 to 127.84 Mha in 1990. It generated employment for everyone, i.e., landholders as well as landless, while ensuring food security for the country. The positive impacts of Green Revolution continued for over 30 years till the 1990s. However in 1990s, the growth in the agricultural sector started facing stagnation.

Growth in Food Grain Production in India

India's food grain production increased five times over six decades, according to 2016 government data. But with the average Indian farm now half as large as it used to be 50 years ago and yields among the lowest in developing economies, both the agriculture sector and farmers have been driven to the brink. Output of food grains in India (Table 5.1) increased from 50.82 million tonnes in 1950–1951 to 252.22 mil-

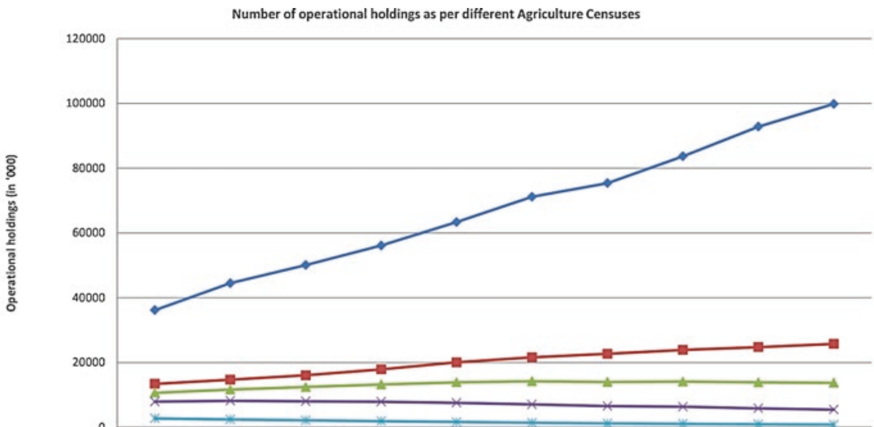
Table 5.1 Growth in food grain production in India

	Food crop production (million tons)				
Year	Rice	Wheat	Coarse cereals	Pulses	Total food grains
1950–1951	20.58	6.46	15.38	8.41	50.82
1960–1961	34.58	11	23.74	12.7	82.02
1970–1971	42.22	23.83	30.55	11.82	108.43
1980–1981	53.63	36.31	29.02	10.63	129.59
1990–1991	74.29	55.14	32.7	14.26	176.39
2000–2001	84.98	69.68	31.08	11.07	196.81
2002–2003	71.82	65.76	26.07	11.13	174.77
2003–2004	88.53	72.15	37.60	14.91	213.19
2004–2005	83.13	68.64	33.46	13.13	198.36
2005–2006	91.79	69.35	34.06	13.39	208.60
2006–2007	93.35	75.81	33.92	14.20	217.28
2007–2008	96.69	78.57	40.76	14.76	230.78
2008–2009	99.18	80.68	40.03	14.57	234.47
2009–2010	89.09	80.80	33.55	14.66	218.11
2010–2011	95.98	86.87	43.68	18.24	244.78
2011–2012	105.30	94.88	42.01	17.09	259.29
2012–2013	105.24	93.51	40.04	18.34	257.13
2013–2014	106.65	95.85	43.29	19.25	265.04
2014–2015	105.48	86.53	42.86	17.15	252.02
2015–2016	104.32	93.50	37.94	16.47	252.22

Source: Directorate of Economics & Statistics, DAC&FW, Government of India lion tonnes in 2015–2016 (*Agriculture Statistics at a Glance, Government of India, 2016).* Also yield increased from 522 kg per hectare (ha) in 1950–1951 to 2056 kg ha^{-1} in 2015–2016. The increase during the first 30 years of the Green Revolution was mainly due to increase in the area under crop production and introduction of improved varieties with recommended cultivation practices. The increase in food production during 1990–2010 can be attributed to improved efficiency and increased use of agri-inputs (particularly insecticides and other pesticides) which also increased the cost of production.

The reason for the low yield is excessive dependence – 52% of India's farmland is not irrigated – on the erratic, uneven, and unpredictable monsoons. The dominance of small and marginal holdings makes this situation highly volatile even more troublesome, as small and marginal farmers are highly vulnerable to adverse climatic conditions. Small and marginal farmers cannot afford to adopt modern techniques of irrigation and production. They also find it hard to use modern machinery on smaller plots. They are stressed and burdened by indebtedness due to successive crop failures and low yields. The impact of these multiple problems is that the agriculture sector's share in India's economy is declining. It contributed 17.5% to the country's gross value added (current price 2011–2012 series) in 2015–2016, down from 18.2% in 2012–2013, 18.6% in 2013–2014, and 18% in 2014–2015. This is expected to decline further (Fig. 5.8).

About 67% of agricultural land in India is held by marginal farmers with farm size less than 1 hectare, while farmers with large holdings (having more than 10 hectares) constitute less than 1%. The area of their holdings that is operated by marginal farmers is low compared to their holdings, but large farm holders get access to a land area



	1970-71	1976-77	1980-81	1985-86	1990-91	1995-96	2000-01	2005-06	2010-11	2015-16
Marginal	36200	44523	50122	56147	63389	71179	75408	83694	92826	99858
Small	13432	14728	16072	17922	20092	21643	22695	23930	24779	25777
Semi-Medium	10681	11666	12455	13252	13923	14261	14021	14127	13896	13776
Medium	7932	8212	8068	7916	7580	7092	6577	6375	5875	5485
Large	2766	2440	2166	1918	1654	1404	1230	1096	973	831

Fig. 5.8 Farm size is changing and the area classified as marginal is increasing. (Source: Agriculture Census 2015–2016, DAC&FW, Government of India)

that is ten times their holdings, indicating the stress marginal farmers face in the country. The average size of the Indian farmland has shrank by over 6% between 2010–2011 and 2015–2016, with operational holding in the country dropping to 1.08 hectares from 1.15 hectares in 2010–2011. With land holding getting smaller, the share of small and marginal holdings in the country (between 0 and 2 hectares) has risen to 86.21% of total operational holding in 2015–2016, which comes to around 126 million, as against 84.97% in 2010–2011. On the other hand, the share of semi-medium and medium operational holdings (2–10 hectares) in total land holdings dropped from 14.29% to 13.22%, while that of large holding (10 hectares and above) fell from 0.71% in 2010–2011 to 0.57% in 2015–2016. This also means the number of small holdings in the country has grown in 5 years, due to fragmentation of land, while that of medium and large holdings have gone down. Total operated area, which includes both cultivated and uncultivated, provided part of it is put to farm use, fell from 159.59 Mha in 2010–2011 to 157.14 Mha in 2015–2016.

The highest number of operational holders belonged to UP – out of the 146 million, around 23.82 million was in UP, followed by Bihar (16.41 million), Maharashtra, Madhya Pradesh, and Karnataka.

Marginal Farmers Most Indebted

About 52% of India's agricultural households are indebted, with an average outstanding loan of Rs 47,000, according to Agricultural Statistics 2016 based on the National Sample Survey Office – Assessment Survey of Agricultural Households (Jan–Dec 2013). The indebtedness varies across states, from 93% in Andhra Pradesh to 2.4% in Meghalaya. Agricultural households with marginal holdings are the most indebted (64%) compared to just 0.6% of households holding large farms. Nearly 70% of India's 90 million agricultural households spend more than they earn on average each month, pushing them toward debt; it was reported in mid-2017 (Mallapur 2017).

About 62.6 million households spending more than they earn had land holdings of 1 hectare or less. In contrast, 0.39% households owning more than 10 hectares of land had an average monthly income of Rs 41,338 and consumption expenditure of Rs 14,447, thereby maintaining a monthly surplus of Rs 26,941 (Fig. 5.9).

Impact of Slow Growth in Agricultural Production

Reduction in the rate of growth in food production has several adverse effects on the farmers, particularly the poor. The per capita availability of food grains has declined after 1990 (Table 5.2). While the availability of rice and wheat marginally declined, there was a drastic reduction in the availability of coarse cereals and pulses. This had a direct impact on the supply of protein and minerals, which accelerated the incidences of malnutrition particularly among pregnant women and children.

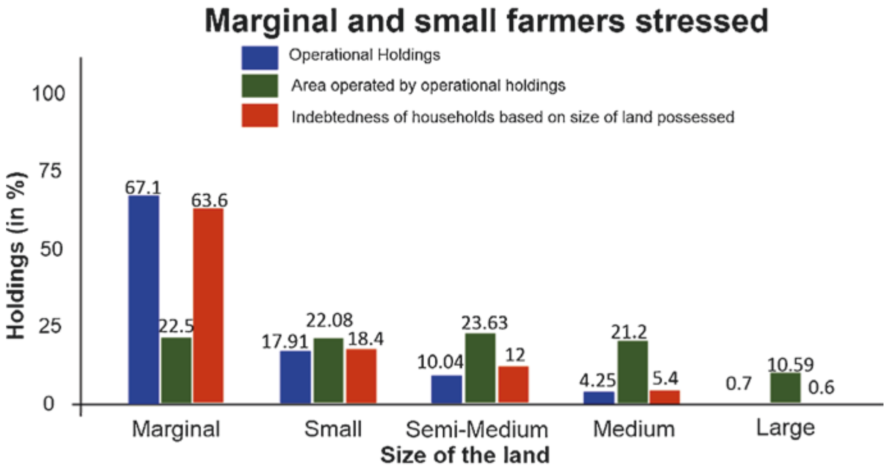


Fig. 5.9 Land fragmentation is a factor in the increasing number of marginal holdings. (Source:Agriculture Census 2010–2011)

Table 5.2 Per capita availability of food grains in India (Kg per capita per year)

Year	Rice	Wheat	Other cereals	Pulses	Food grains
1951	58.0	24.0	40.0	22.1	144.1
1961	73.4	28.9	43.6	25.2	171.1
1971	70.3	37.8	44.3	18.7	171.1
1981	72.2	47.3	32.8	13.7	166.0
1991	80.9	60.0	29.2	15.2	186.2
2001	69.5	49.6	20.5	10.9	151.9
2002	83.5	60.8	23.1	12.9	180.4
2003	66.2	65.8	17.1	10.6	159.7
2004	71.3	59.2	25.3	13.1	159.9
2005	64.7	56.3	21.7	11.5	154.2
2006	72.3	56.3	22.1	11.8	162.5
2007	71.8	57.0	20.8	10.7	160.4
2010	64.0	53.0	19.7	15.3	159.2
2011	66.3	59.7	23.9	15.7	170.9
2012	69.4	57.8	21.9	15.2	169.3
2013	72.1	66.8	19.2	15.8	179.5
2014	72.3	66.8	22.8	16.9	178.6
2015	67.9	61.3	28.4	16.0	169.8
2016	67.2	72.9	26.1	15.9	177.9
2017	69.3	70.1	30.0	19.9	184.7

Source: https://eands.dacnet.nic.in/PDF/PerCapita-FoodGrains.pdf

Stagnation in agricultural production has also been suppressing the employment opportunities in this sector. As a result, contribution of agriculture to the national GDP has come down drastically from 58% in 1951 to 35% in 1991 and to 17% in 2009. However, the population dependent on agriculture in the country reduced marginally from 70% in 1951 to 60% in 2009. This has been affecting the income of the rural families and their capacity to purchase food. Thus, the per capita food consumption in rural India has been decreasing significantly over the last 25 years and threatening food security. Landless, small, and marginal groups are facing vulnerability.

Small Farms Are Very Efficient

Despite their small size (maybe partly because of it), efficiency levels are high. Worldwide, and especially in the developing world, the production of food has increased ahead of population growth for most of the last 50 years. Much of this increase in availability has come from small-scale family farms, particularly in Asia. Taking Asia as an example, we can see that 90% of the rice, 40% of other cereal grains, and 40% of the meat is produced there – most of it by smallholders. Smallholders in Africa, Asia, and Latin America focus on real food security for survival. Smallholders play a critical role in such food security in the poor world. They feed themselves and their families and in some cases sell their surplus to feed rural towns and even peri-urban markets.

The report of Lerman and Sedick (2011) for FAO *Policy studies on rural transition 2003-9 in Central Asian agriculture* demonstrates higher productivity of small farms, especially household plots. Falvey (2010) notes that "the Asian smallholder has consistently fed Asia, generated exports and accepted technological innovations while feeding himself and enjoying less social protection (price support/subsidies) than his compatriots." This is quite a compliment! And they are very efficient. Small farmer yields under these intensive conditions are often higher than under the extensive broad acre systems common in rich countries. The advantages of small farms over larger ones (Table 5.3) is well documented (Braun 2009). Smallholder production offers specific skills that may not be accessible in broad acre agriculture, such as

Table 5.3 Some comparisons related to transaction costs of small and large farms*. (Modified from Global Donor Platform for Rural Development, https:/www.donorplatform.org/)

Small farms	Large farms
– Close supervision of farm household labor – Detailed farm knowledge down to small areas, plants, and animals – Feeding the family on fresh produce direct from the farm – Empathy with livestock and high levels of animal welfare	– Sourcing and managing skilled labor – Access to technologies and markets – Deals on inputs, credit, contracted and bulk sales, government favors – More secure tenure over land – Possible quality assurance (QA) of produce across the supply train

preprocessing on the farm, orientation to specific markets including organic produce, and maintaining competitive cost structures. A review by the Australian Centre for International Agricultural Research (ACIAR) presents some instances in which smallholder initiatives produced higher returns than alternatives such as:

- The shift from plantation tea to small farm tea production in Sri Lanka
- Sulawesi cocoa growers who receive an unprecedentedly high 80% of the world price at their farm gate from an industry started by their own initiative
- Vietnam cassava growers who have graduated from being price-takers for bulk carbohydrate raw material by seeking new varieties to service 60 new local starch factories and are now considering expansion to produce biofuel that does not conflict with food production

These examples relate to cash crops, but the same applies to home food production. Table 5.3 shows that there are different transaction cost advantages that apply to small and large farms.

Small farms are vibrant interactions between diverse plants and animals, including the farmer and his family. It is easy to elicit the virtues of small farms in comparison to broad acre farms, but this pits broad acre farms against small farms when the world is not only big enough for both but urgently needs both. It needs to accommodate each in its own niche in social, humanitarian, environmental, and commercial terms. All sizes of farms and variations on labor use are necessary to meet the total food requirements of the world. But it is the neglected small farms that benefit more people. As we have said before, smallholders feed half of the world's population. As suggested by Wiggins and Keats (2013), smallholder agriculture can potentially affect food security and nutrition through the following pathways:

1. Making food available through production.
2. Reducing the real cost of food, by increasing the supply of food. The composition of production also matters, since this affects the availability and prices of different foods with their varying nutrients.
3. Generating incomes for farmers and, for those working the land as laborers, gives access to food and, through this, employment opportunity.
4. Providing incomes to others in the rural economy from linkages in production and consumption that create additional activity and jobs.

Box 5.1 Existing Technologies Are a Starting Point for Adaptation to Climate Variability

Many technologies already exist that could facilitate adaptation by smallholder farmers when customized for local conditions and made available and affordable. Examples include the following: Change varieties or species of crops, or rear different breeds or species of livestock (or fish in aquaculture), including neglected crops and breeds. Varieties or breeds with different environmental optima may need to be adopted or those with broader environmental

(continued)

Box 5.1 (continued)

tolerances. Increase diversification of crops to hedge against risk of individual crop failure. Make use of integrated systems involving livestock and/or aquaculture to improve resilience. ƒ Change planting dates for food crops, feeds, and forage. ƒ Change irrigation practices to reduce water use. Make more use of rainwater harvesting. In some areas, increased precipitation may allow rainfed agriculture in places where previously it was not possible. ƒ Use reduced tillage to lessen water loss. ƒ Incorporate manures and compost. ƒ Plant cover crops to increase soil organic matter and improve water retention. ƒ Alter animal diets and stocking rates. Prepare for increased frequency of extreme events, including putting in place water conservation measures in times of drought, increasing soil organic matter to help store water after storms, and improving drainage and farm design to avoid soil loss and gullying. Farms in coastal areas may need to adapt to increased frequency of saltwater intrusions and those in dryer areas to more frequent wildfires. ƒ Adopt integrated management strategies as pest, weed, and diseases respond to climate change. Recognize that the natural regulation of potential pests by their natural enemies may be disrupted by a changing climate. ƒ Engage with other food producers to share best practice and experience so as to enhance community-based adaptation. ƒ Recognize that where wild plants and animals supplement diets, climate change will alter their availability in ways difficult to predict. Farmers with larger holdings tend to be more mechanized, use more tillage, and rely predominantly on cultivation of single crops. For climate resilience they should explore low- and no-till options; improve management of the resources applied, including nutrients and water, to support soil health; diversify crop production; and rotate crops.

Source: HLPE 2012.

Box 5.2 Reducing Postharvest Losses Can Help Combat Food and Nutrition Insecurity in the Face of Climate Change

In the developing world, on-farm, postharvest food loss is substantial. Sources of loss include harvesting methods, handling techniques, type or availability of storage, and contamination from pests and pathogens. Climate change could increase the losses. Many new programs to reduce postharvest losses are under way. Two are highlighted here.

Burkino Faso

In Burkino Faso, USAID and Catholic Relief services supported the development and distribution of tripled-lined storage bags that are airtight, warding off pests and eliminating the need for chemicals to protect the contents. These bags increase storage life, improve food quality and safety, and allow farmers to sell produce when prices are higher.

(continued)

Box 5.2 (continued)

Nigeria

Postharvest loss is also being combated in Nigeria where smallholder cassava growers struggle to process cassava roots quickly before they deteriorate. USAID, the International Institute of Tropical Agriculture, and the Shell Petroleum Development company created the Cassava Enterprise Development project, which provides smallholder farmers with tools such as industrial root washers, peelers, and graters to facilitate postharvest processing.

Source: The World Bank 2013; USAID 2013; Integrated Cassava Project 2014.

Barriers and Limits to Adaptation for Smallholders

The impacts of climate change are experienced locally, and therefore, geographic variability in climate impacts emphasizes the need for "place-based" approaches to climate vulnerability analysis and adaption. The term "place-based" refers to a spatially distinct group of biophysical and social conditions, which can, in principle, occur at any scale but tend to focus at local scales where local drivers manifest themselves in particular ways.

Adaptation involves changes in social-ecological systems in response to actual and expected impacts of climate change in the context of interacting non-climatic changes. Closely related to the need of adaptation is the concept of vulnerability. This is the case, because factors like adaptive capacity or sensitivity have effects on vulnerability and adaptation mainly seeks to reduce vulnerability. Adaptation and adaptive capacity have the potential to reduce vulnerability.

Adaptation strategies and actions can range from short-term coping to longer-term, deeper transformations, aim to meet more than climate change goals alone, and may or may not succeed in moderating harm or exploiting beneficial opportunities. Generally defined, barriers to adaptation are challenges, obstacles, constraints, or hurdles that impede adaptation. Barriers are defined here as obstacles that can be overcome with concerted effort, creative management, change of thinking, prioritization, and related shifts in resources, land uses, institutions, etc. Only a small subset of all suggested adaptation measures will be implemented due to technical and physical limits as well as to differences in objectives.

Vulnerability of Smallholders to Global (Including Climate) Change

Across the world, smallholder farmers already face numerous risks to agricultural production. But despite their direct contribution to food production, small-scale farmers and their households are disproportionately vulnerable to hunger and to

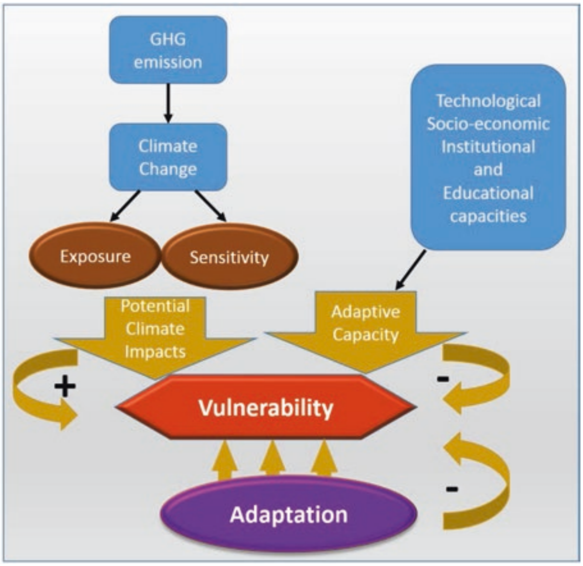


Fig. 5.10 Climate change influences both exposure and sensitivity and therefore creates potential climate impacts, which in turn increase vulnerability. Adaptation and adaptive capacity have the potential to reduce vulnerability

malnutrition. Interventions to promote smallholder well-being should be developed to recognize smallholders as a dynamic group with potential future livelihoods on their own farms, in other rural sectors, and in cities near and far (see Fig. 5.10).

Climate Change Poses Risks to Global Food Security

Climate change will further increase food- and agriculture-related conflicts. The impacts of climate change include increased water and heat stress, damaged ecosystems, and rising sea levels. The actual effects are heterogeneous and region specific. Yet, in most cases, the harmful effects outweigh the benefits and disproportionately hurt the poorest, who have the least capacity for adaptation. By the 2050s, for example, there will be twice as many areas with increasing water stress due to climate change than there will be areas with decreasing water stress. In addition, heat stress may reduce grain yields in Asia by 15–20% by 2050. And the effects of climate change are expected to further increase the number of undernourished people in sub-Saharan Africa. All of these impacts are likely to increase food- and agriculture-related conflicts as well.

Climate change is expected to disproportionately affect smallholder farmers and make their livelihoods even more precarious. Many smallholders are vulnerable to climate change in ways that other farmers are not. The production risks posed by climate shocks may interact with other stressors, including infectious diseases, nutritional deficiencies, natural resource degradation, and insecure land tenure to compound risks to smallholder livelihoods. Hundreds of millions of the world's poorest people directly depend on smallholder farming systems. These people now face a changing climate and associated societal responses. Smallholder farming systems will become a critical fulcrum between climate change and sustainable development (Cohn et al. 2017). Because smallholder farmers typically depend directly on agriculture for their livelihoods and have limited resources and capacity to cope with shocks, any reductions to agricultural productivity can have significant impacts on their food security, nutrition, income, and well-being.

Farmers are particularly vulnerable to any shocks to their agricultural system owing to their high dependence on agriculture for their livelihoods, chronic food insecurity, physical isolation, and lack of access to formal socioeconomic safety nets. Farmers are frequently exposed to pest and disease outbreaks and extreme weather events (particularly cyclones), which cause significant crop and income losses and exacerbate food insecurity.

As Falvey (2010) points out, if sea levels rise by 300 mm as the majority of the models predict, the fertile river deltas of Asia and Africa will be at risk, of increased saltwater intrusion (as is already happening in the Nile Delta), river siltation, and course change, flooding, and damage from more frequent and severe storms, tidal surges, etc. Loss of lives and property, that is, small holder's lives and farms will be lost to climate change. This is serious for two reasons: first, much of the world's food comes from such low lying deltas, and second, broad acre farming has already significantly displaced smallholders on many non-delta lands leaving delta farmers as a last and now vulnerable repository of advanced small farming innovation. If sea levels rose by 1 meter – the worst case scenario – it has been calculated that this would displace some six million people from 13% of arable land in Egypt, some 13 million producing 16% of rice in Bangladesh, and some 72 million from unspecified large areas of China. These deltas are very expensive to protect, but the value to the many societies is significant.

According to Falvey (2010), the practical response is to use realistic predictions in survival food security policies as a guide for major technology development oriented to smallholders in deltas. Such technology would build on the past innovations of the farmers themselves. For example, smallholders have evolved tide-driven irrigation schemes in the Mekong Delta, acid sulfate soil flushing technologies in the serai of Vietnam, natural soil renewal management systems in the Nile Delta, and highly integrated ecosystem agriculture in the Chinese river deltas. Retention of this knowledge, coupled with means of continuing to use what has been the world's most productive agricultural land, is the task of policy and research. Policies that promote low-input sustainable agriculture should be favored. Any analysis of the cost-effectiveness of traditional delta user agriculture would favor continued investment in delta regions using the smallholder model. Smallholder's attention to individual plants and animals, intensive pest, and nutrient management maximizes use of such valuable land. By contrast, simplistic engineering solutions for large cities such as piping sewage far away from productive agricultural areas reduces food production. Yet major cities arose from deltas with harvested nutrients returned to agriculture. Technologies for healthily recycling solids and wastewater allow a return to seminatural processes. Once again, China reminds us that millions of tons of pig and human waste used on small farms reduces the need for chemical fertilizers and enhances food crop production. The general approach of nutrient tracking and recycling can be applied to all food production systems.

A different kind of risk to survival food security is the genetic erosion that is hidden in homogenized agriculture and the narrowing of the genetic base of food plants and the loss of indigenous breeds of livestock, especially poultry. Erosion of genetic diversity in agriculture is a problem. It is only recently that fields restricted to single species and varieties have become common. The introduction of modern varieties and breeds has almost always displaced traditional varieties and breeds. The twentieth century saw the loss of some 75% of the genetic diversity of agricultural crops. Only about 150 plants species are now cultivated, of which just three supply almost 60% of calories derived from plants. Such erosion of genetic diversity in agriculture represents a major threat to the food security of the majority of the region's producers. Modern, uniform crop varieties will only reach their potential if the environment is also uniform, which means high-quality land where the fertility and water status have been evened out with the use of fertilizers and irrigation. In areas where mono-cropping is prevalent, diseases and pests can spread quickly and cause devastation. While improved methods of controlling animal and crop diseases are now available, the costs of these services have become increasingly prohibitive for the farmer. This narrowing is making vast areas of agricultural land vulnerable to specific diseases or pests. Thankfully smallholders choose varieties, genotypes that differ from the mainstream for such reasons as flavor, ease of intensive crop management, or just availability of seed or other necessities. Family poultry (village chickens) are case in point (Wong et al. 2019).

Farmers of traditional and low-input agricultural systems have long favored crop diversity. Even today, there are still a huge variety of crop combinations cultivated, including cereals, legumes, root crops, vegetables, and tree crops. Cereals may be intercropped, producing, in some cases, highly complex patterns, with up to ten species grown in close proximity. In very variable conditions, farmers rarely standardize their practices. They maintain diversity, develop a variety of strategies, and so spread risk. Mixtures of crop and varieties clearly provide farmers with a range of outputs and also represent a logical approach to coping with variable environments. Mixed crops can also be less variable in time and space, and combined yields are often greater, particularly if differences in root and shoot geometry allow the crops to use light, nutrients, and water more efficiently Intercropping can reduce weed problems, so influence labor requirements, returns to labor can be increased, and erosion and runoff may be reduced because of the greater ground cover given by the mixture. Crop genetic diversity provides security for farmers against pests, disease, and unexpected climatic conditions. In the highly variable environments of Asia, Africa, and Latin America, crop genetic diversity can help small-scale farmers obtain higher yields than they could with monocropping. Higher yields are obtained from a mixture of crops and crop varieties, each one specifically adapted to the microenvironment in which it grows. Genetic diversity also provides farming communities with a range of products with multiple uses and value. Some varieties of a particular crop may be good for immediate consumption, for example, while others are better for long-term storage.

The mixed farm of the smallholder can be an almost closed system, making little impact on the outside world: crop residues are fed to livestock or incorporated in the soil; manure is returned to the land in amounts that can be absorbed and used; legumes fix nitrogen; trees and hedges bind the soil and provide valuable fodder and fuel wood and habitats for predators of pests. The components of the farm are thus complementary in their functions, with little distinction between products and by-products. Both flow from one component to another, only passing off the farm when the household decides they should be marketed. It is also important to keep in mind that, in some circumstances, modern agriculture undermines food security and health by putting the rural poor at a disadvantage, threatening their land tenure, and degrading basic resource such as water and soil.

Small Farms with Irrigation – A Miraculous Combination

The most productive lands outside small farms in deltas are small farms with irrigation. The volume of food produced in poor countries is miraculous. From regions destined for mass starvation, huge increases in population have been exceeded by greater increases in food production. Today the two most populous countries in the world are food exporters. Smallholder initiative has filled the gap. For an example that relates to irrigation in Asia where 70% of the world's 277 Mha or irrigated land covers 34% of Asia's arable land, that produces 60% of its food grains, mostly from small farms. Smallholders have found ways of complementing or even bypassing state-built irrigation schemes. They have done this, for example, by innovatively pumping from aquifers and rivers and building on-farm storages. Such measures supply a significant amount of irrigation water for small farms across large areas of South, East, Central, and Southeast Asia. It is clearly impossible to support creation of centrally designed irrigation schemes that ignore the specific water needs of smallholders. The same smallholders who have been innovative in accessing water have increased crop yields at the same time. Of course unregulated groundwater pumping has led in places to massive drawdown and resource depletion. The practical response is not to ban pumping but to look to the priorities expressed by the smallholders' decisions, which in this case would suggest that past water delivery schemes have met neither the scheme's nor the smallholders' objectives. Practical, smallholder-focused policy would be integrated with development of further irrigation potential. Potential still exists, despite conservative reports to the contrary. The two major food producers, India and China, provide examples. India claims it has potential of 113 million irrigable hectares compared to its current total of 57, while China's 58 million irrigable hectares is said to be expandable to 64. Even in Southeast Asia, the current 17 million irrigable hectares could potentially be expanded to 44 Mha. Expansion of irrigation in many areas is only possible by increased water use efficiency, an approach taken by China's development in its water-saving technologies in parallel with institutional innovations and the spread of water user associations (Xu et al. 2014). Water use efficiency has been essential to success everywhere, and this has been driven by research on agronomy and more investment in infrastructure (roads in particular). Adaptive research that might show how advances in science and technology (including climate-smart agriculture) might benefit smallholders is poorly funded.

Between 1980 and 2004 in China, there was a 25% rise in irrigated area. This occurred without a significant increase in water requirements: irrigated area increased by 5.4 Mha and food production by some 20 million tons, thereby allowing 200 million more people to become food secure. It is from such practical experience that other countries will develop their food security, using their smallholder production bases. Indonesia in its *Water Resources Law* acknowledges water rights for small-scale agriculture. The *Law* says "regardless of the financial questions, there is strong case for protecting the water rights of smallholders, particularly in areas where development change is expected, to ensure that their interests are fully recognized in any change process."

Farmers of the Sea

Likewise, the small farmers' cousins of the sea, small-scale artisanal fishers, have millennia-old traditions to husband community fish resources. These are now subject to commercial encroachment, piracy, and pollution; such artisanal fishers and their care of the basic resources are being lost, and a rear guard action is being vainly fought to legislate protection of remaining marine breeding resources to counter clearing of mangroves to make way for aquaculture (fish farms). Regulation of dredging of waterways to allow larger ships to traverse and measures to reduce turbidity of waters that comes from larger ship propellers, etc. need to be implemented. The marine situation mimics that on the hinterland, with declines in small fisher numbers and concomitant risks to future production. The capture production of fish has been declining, with aquaculture making up the difference, which is about half of all consumption with the same narrowing of diversity that characterizes other farmed food production. The potential for technological development remains high as the whole field has been neglected compared to land-based food production. But the promotion of policy initiatives that are firm on resource and small fisher protection within the overall staple food security policy as reflected in strong regulations and determined policing are yet to formulated.

Beyond the delta, seas, and irrigated areas at the other end of the environmental water regime are the 40% of the rural population in developing countries who live in less favorable agricultural areas – mainly drylands (Squires and Ariapour 2018). These dryland areas vary markedly and cover 41% of the earth's land surface (about 6 billion ha) and support, according to FAO, about two billion people (Squires and

Gaur 2019). In some cases, innovations allow profitable crop or livestock production. Technologies and social systems that encourage improvements to smallholding subsistence animal husbandry and crop agriculture in these regions are poorly represented in research and development programs (Squires and Bryden 2019).

Food Security in Drylands Uunder Global Climate Change

Pastoral production systems are the mainstay of livelihoods in drylands. They are found in climatic zones as different as deserts, dry plains, savannahs, steppes, tundra, and high-altitude mountain ranges, but all have in common the exploitation of ephemeral concentrations of resources (Behnke et al. 2011; Asner et al. (2004) estimate that about 26 million km^2 of land in these biomes worldwide are under managed-grazing systems, which is more than the combined areas of USA, China, and the European Union. Rass (2006) estimates that there are about "120 million pastoralists/agro-pastoralists worldwide," 50 million of which are in sub-Saharan Africa, 31 million in West Asia and North Africa, 25 million in Central Asia, 10 million in South Asia, and 5 million in Central and South America.

Besides using strategic mobility and livestock feeding selectivity, pastoralist smallholders interface the instability of their operating conditions with a high degree of diversity within the production system itself. A common strategy is keeping a variety of livestock species with different feed requirements and providing different products and functions to the household (e.g., small stock for covering small expenses and large stock for milk production and annual sales).

Data recently published by the FAO indicate that human-edible protein from livestock is produced much more efficiently in countries where the sector is dominated by pastoralism, with protein input/output ratios between 1:4 and 1:21 in India, Sudan, Mongolia, Ethiopia, and Kenya compared with those of intensive livestock systems where the ratios are well below or around 1:1 in Saudi Arabia, USA, Germany, China, the Netherlands, and Brazil. This also highlights the comparative advantage for livestock production in pastoral systems over intensive systems with regard to the dependence on fossil fuels (as pastoralism is a low-carbon production system) and the limited use of cultivated fodder or competition with food crops (Steinfeld et al. 2010).

Climate change is a global phenomenon, but the impacts of related food crises are expected to be greater in Asia, particularly in the context of the region's industrial structure, population structure, and food culture. Climate change directly impacts agro-ecosystems that are at the heart of efforts to ensure food security (Figs. 5.10 and 5.11).

Postharvest losses (see Box 5.1 and 5.2) must be minimized. In the long term, it will be necessary to actively and proactively respond to future food crises at the national and international levels. It is necessary to address food security in its broadest sense and integrate it in the development of agriculture worldwide. "Climate-smart agriculture" can be built up by improving technology and management systems to achieve global food security (Wheeler and Braun 2013).

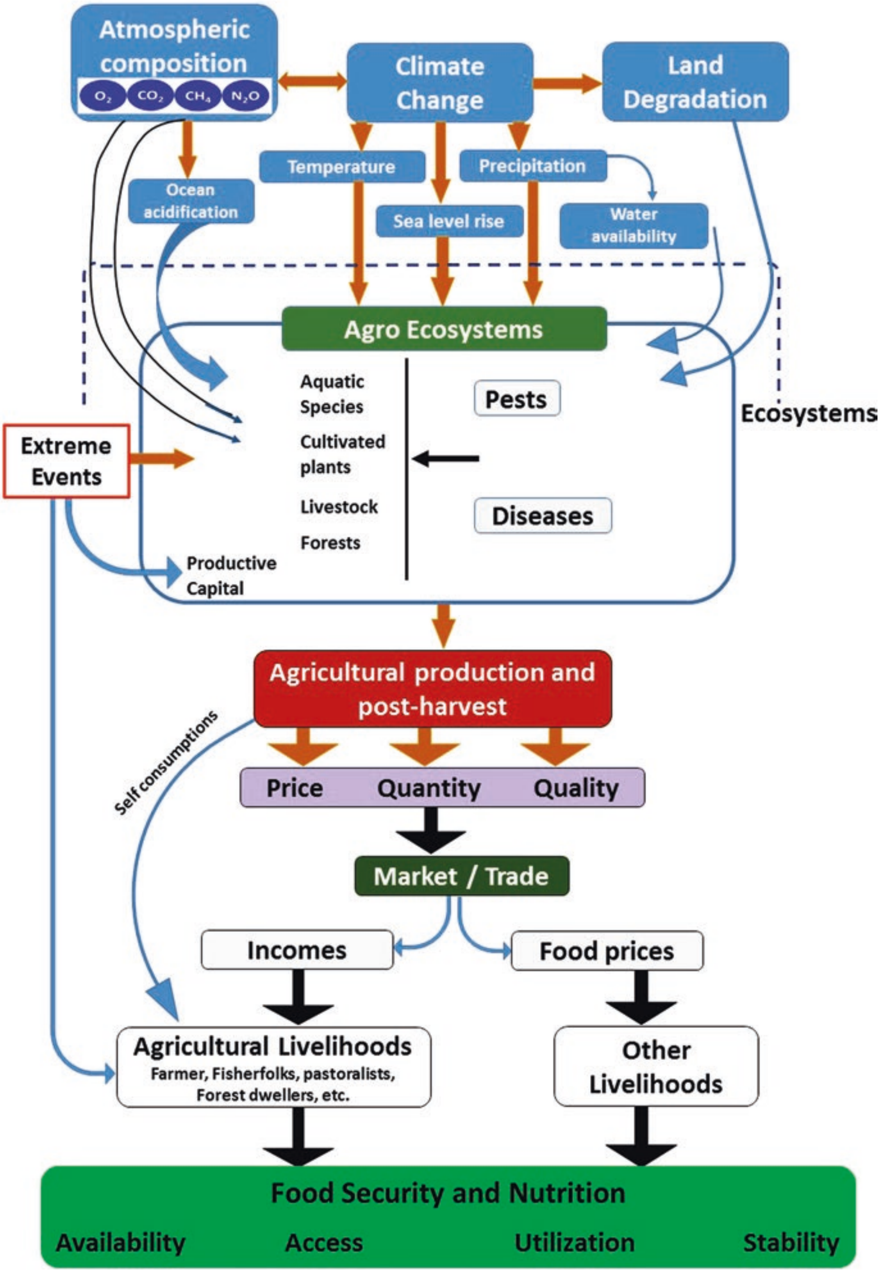


Fig. 5.11 Climate change impacts agroecosystems and exacerbates the problems of ensuring food security

Food Production Under Conditions of Environmental Instability

Livestock provides more food security than growing crops in many arid and semi-arid areas. Comparing nutritional status of children from nomadic and sedentary population groups in Mali, Pedersen and Benjaminsen (2008) conclude that farming appears to be a poorer adaptation than nomadic pastoralism in arid environments such as the northern Sahel. Mobile pastoral systems in both West and East Africa were found to perform better than sedentary systems under the same conditions. Sulieman and Young (2019) found that "in almost every production parameter, the performance of the former is superior to that of the latter." In Niger, nomadism was found to increase productivity by 27% compared with sedentary livestock systems and by 10% compared with transhumant systems.

One of the most critical analyses of the environmental impact of the livestock sector – 'Livestock's Long Shadow – found that "If properly managed, nomadic pastoral livestock production is potentially the most environmentally compatible agricultural activity in this ecosystem [drylands]" (Steinfeld et al. 2006, p. 260).

Increasing the productivity and resilience of smallholder farming systems is a huge challenge that will require significant and sustained technical, financial, and political support and action at both the national and local levels. However, a handful of low-cost and local approaches – such as revitalizing farmer extension services, implementing small-scale local infrastructure projects with farmers, strengthening informal safety nets, and safeguarding natural ecosystems – could go a long way toward beginning to address this critical challenge and improving the livelihoods of smallholder farmers

A priority for policymakers is to safeguard the natural ecosystems that smallholder farmers use as safety nets. Forests, wetlands, rivers, and other natural areas provide critical ecosystem services to smallholder farmers, including the provision of firewood and charcoal, water, wild foods, and materials for house construction, among others. These services are important year-round but particularly following catastrophic events when farmers turn to the forests for food and materials to rebuild their damaged homes. Efforts that conserve, restore, or sustainably manage these natural ecosystems are therefore crucial for sustaining farmer livelihoods.

Particular attention must be paid to raising agricultural productivity, as this could make a significant difference in food insecurity and poverty levels, both by increasing the total food availability to households and improving household income generation (Sanchez and Swaminathan 2005). Agricultural growth has been shown to be 2.2 times as effective at reducing poverty as growth in nonagricultural sectors indicating the critical role that improving agricultural productivity should play in development strategies.

Women and Food Security

Women play a major role in agriculture and food security and thus need to be equal partners in dealing with the challenges of climate change. Women are involved in food production as farm managers and laborers, they earn income that helps their families grow and (sometimes) purchase food, and they are largely responsible for preparing food within the household. In developing countries, on average women make up more than 40% of the agricultural workforce, ranging from 20% in Latin America to 50% in parts of Asia and Africa. Yet there is a substantial gender gap in access to agricultural inputs, with serious implications for agricultural productivity (Elham 2019). There are limited systematic gender-disaggregated data on land ownership, but the few studies that exist point to large gaps in land holdings, with women owning as little as 5% of agricultural land in West Asia and North Africa. In West Asia and North Africa, less than 5% of agricultural land holders are women; in sub-Saharan Africa, women hold approximately 15% of agricultural land. A recent study in the state of Karnataka in India found that women held 9% of the land.

For female-headed households that do own land, plots are usually smaller than those of male-headed households on average. Women also own fewer livestock and have inferior access to productive inputs and services, including credit, technology, equipment, extension services, fertilizers, water, and agricultural labor. These constraints as well as others directly affect women's farm productivity. According to the FAO, by addressing the gender gap in agriculture, developing countries could experience gains in GDP of 2.5–4% with an associated decline of 12–17% in undernourished people. These inequities must be taken into account, and efforts to adapt to climate change must address them to take full advantage of the contributions women can make. Women have varying roles in food systems in different parts of the world. Effective planning for adaptation should anticipate the consequences on gender-specific workloads and effects on existing inequalities between men and women both within households and communities. Institutional and social changes are often essential elements of adaptation.

Although farmers use a variety of risk-coping strategies, these may be insufficient to prevent them from remaining food insecure. Few farmers have adjusted their farming strategies in response to climate change, owing to limited resources and capacity. At the same time, smallholder farmers have myriad adaptive capacities, including knowledge, networks, and management practices that have long enabled smallholder systems to cope with both environmental and socioeconomic change under a changing climate. It is likely that these adaptive capacities will manifest differently from adaptive capacities employed in other farming systems.

Smallholders face many barriers to adaptation, including limited economic and financial resources, lack of access to usable information, unavailability of appropriate technologies for different users, credit constraints, lower socioeconomic and educational status of users, and limited access to social networks (96–100). These constraints can lead smallholders to have lower levels of risk tolerance compared to other farmers, which also influences adoption of new ideas technologies, etc.

Summing Up

Many of the rural poor are subsistence farmers or landless people seeking to sell their labor. They depend on agriculture for their earnings, either directly, as producers or hired workers, or indirectly, in sectors that derive from farming. For example, trading, transportation, and processing involve large numbers of small entrepreneurs and are necessary for agriculture, but, at the same time, such entrepreneurs depend on farming activities for their survival. Food-insecure people neither consistently produce enough food for themselves nor have the purchasing power to buy food from other producers. During times of famine, food may simply not be available at any price. Fortunately, few places experience famine, but many suffer from food insecurity. In the developing countries, 70–75% of the poor and hungry live in rural areas. Farming is, therefore, at the heart of their livelihood strategies. The International Fund for Agricultural Development (IFAD 2001) and the new World Bank Rural Development Strategy (FAO 2002: 8) have reiterated the importance of farming as worsening standards of living in rural areas drive desperate people to the cities, thereby exacerbating urban poverty and a further decline of agriculture and the rural sector.

Smallholders are here to stay for the foreseeable future. Not only that, they are essential as a key to the best possible scenario of providing basic food for reasonably healthy survival of the majority of the world's poor, including two billion of themselves.

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Chapter 6
Climate Change and Food Security in the Bamenda Highlands of Cameroon

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Introduction

Climate variability and change is a socio-ecological system which cannot be understood and evaluated by relying on physical sciences alone because its effects trickle down to the lowest level of society, particularly in rural communities (Tume and Tanyanyiwa 2018). This stems from the fact that rural communities rely on climate-sensitive sectors that include agriculture and other primary activities for their livelihoods. Climate variability and change has exacerbated food supply issues by impacting adversely on crop production, food security, and availability as well as crop distribution (Ericksen et al. 2010). With the shifting precipitation patterns and the rise of land and ocean surface temperatures by 0.65–1.06 °C between 1880 and 2012 (IPCC 2013), there has been a decrease in crop yields exacerbated by the shifting precipitation patterns and decreased crop yields that are expected with climate change which has pushed many developing countries to become increasingly dependent on food imports. At the same time, pressure to cultivate marginal land or use unsustainable cultivation practices may lead to increased land degradation (Biermann et al. 2016). Food and resource scarcity is particularly problematic in the developing world, which is heavily reliant upon local resources for day-to-day survival (Newbold 2010; Weeks 2008). Climate change could further jeopardize food crops and security as precipitation patterns shift and temperatures increase (Collier et al. 2008). On its own, climate change is estimated to increase the number of malnourished between 40 and 170 million globally. Even slight increases in temperature are expected to reduce crop yields, particularly in tropical latitudes, including sub-Saharan Africa (SSA) (Hasan et al. 2017).

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Extreme weather events such as droughts in some of the agroecological domain and floods in others are the main triggers of agrarian vulnerability in the sub-Saharan Africa (Mathews et al. 2014; Kinuthia et al. 2018). Unlike flooding, drought is a recurrent phenomenon in all the microclimatic environments though its onset is slow and imperceptible. There is an established consensus that climate is changing and impacting more negatively than positively on agricultural livelihood systems (Tume and Fogwe 2018). Frequent irregular onset of the rains complicates practices and the sustainability of such rain-fed agriculture in the Bamenda Highlands. Since the full implications of climate change for development are currently not clearly understood, the poor often cannot adopt diversification as an adaptive strategy because they have limited diversification options.

Agriculture contributes about 70% of the GDP of some sub-Saharan African (SSA) economies (Campbell et al. 2011). Climate variability is projected to reduce yields from rain-fed agriculture by up to 50% by 2020 in Africa (Campbell et al. 2011). Rain-fed lands account for more than 80% of global crop area and 60% of global food output but are especially susceptible to the impacts of climate change. In Cameroon, agriculture directly employs about 80% of the work force and more than 90% on some rural areas of the Bamenda Highlands of Cameroon (Tume and Fogwe 2018).

Study Area and Methods

The Bamenda Highlands is part of the Cameroon volcanic line (CVL) that is a mountainous landscape rising as high as Mount Oku (3011masl) cut across by a series of plains and extensive valleys (Fig. 6.1).

The geology of this highland is volcanic which acts as aquifers that directly determine the water supply to one of three agrarian production basins (Tume et al. 2018). The area has two seasons being the wet season from mid-March/April to October and the dry season from November to mid-March. This highland has microclimatic zones: cold, cloudy, and misty zone; cool misty zone; dominantly warm and wet climatic conditions; and variable conditions dominated by hot, wet, and sunny conditions. This microclimatic zonation aligns with the topography to constitute a blend of micro agroecological basins where climate change (long term) and variability (inter-annual, intra-annual) are major environmental challenges confronting crop production systems. These systems are part of the larger three agrodomains of the Bamenda Highlands which are:

- The low-altitude agroecological domain of less than 800 masl that extends on parts of Mezam, Donga Mantung, Bui, Boyo, Menchum, and Momo. The specific farming localities are Bafut, Ako, Nwa, Nvem, Belo, Njinikom, Menchum Valley, Fundong, Ngie, Njikwa, Widikum, and Batibo. The dominant fruits in these localities that are remarkably affected by climate change and vulnerabilities yet are fundamental to farmers' livelihoods are citrus, avocado, mango, pineapple, plum, guava, pawpaw, banana, and oil palm.

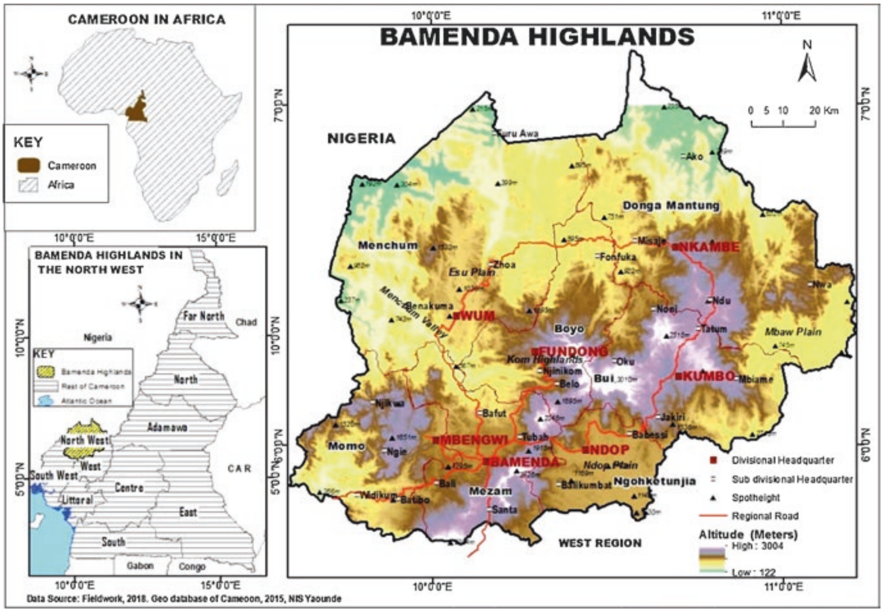

Fig. 6.1 Location of the Bamenda Highlands

- The mid-altitude agroecological domain lies between 800 and 1400 masl and extends on parts of Mezam, Ngoketunjia, Donga Mantung, Bui, Boyo, Menchum, and Momo. The specific farming localities are Tubah, Bafut, Bali, Bamenda Central, Babessi, Ndop, Balikumbat, Mbengwi, Batibo, Njikwa, Wum, Fungom, Fundong, Belo, Njinikom, Bum, Noni, Mbiame, Kumbo, Jakiri, Mesaje, and Nwa.
- The high-altitude agroecological domain above 1400 masl that extends on parts of Mezam, Donga Mantung, Bui, Boyo, and Momo. The specific farming localities are Santa, Batibo, Fundong, Belo, Njinikom, Oku, Noni, Kumbo, Nkambe, and Ndu.

In order to assess the effects of climate variability and change on food security, the rainfall parameter was considered for investigating climate variability and change. Rainfall data was collected from ten stations spread all over the Bamenda Highlands, namely, Ndu (62 years), Jakiri (58 years), Tubah (18 years), MbawNso (43 years), Takui (20 years), Santa (38 years), Bamenda (55 years), Ndop (29 years), Oku (33 years), and Belo (30 years). Rainfall data was treated using rainfall anomaly index (RAI). RAI, designed by van Rooy (1965), considers the rank of the precipitation values to calculate positive and negative precipitation anomalies. RAI positive and negative were calculated using the following equations:

$$RAI = +3\frac{RF - M_{RF}}{MH_{10} - M_{RF}} \text{(Positive anomalies)}$$

$$RAI = -3\frac{RF - M_{RF}}{ML_{10} - M_{RF}}\text{(Negative anomalies)}$$

where:

RAI = the rainfall anomaly index
RF = the rainfall for the year in question
M_{RF} = the mean actual annual rainfall for the total length of the period
MH_{10} and ML_{10} = the mean of ten highest and lowest values of rainfall (RF), respectively, of the period

RAI-normalized precipitation values are based on weather history at a particular location. The only input parameter is precipitation. It reflects droughts that impact agriculture, water resources, and other sectors. RAI is flexible in that it can be analyzed at various time scales (World Meteorological Organization-WMO 2016). It is easy to calculate, with a single input (precipitation) that can be analyzed on a monthly, seasonal, and annual time scales. For this study, the annual time scale is used. RAI classification ranges from ≥3.0 (extremely wet) to ≤ -3.00 (extremely dry) (Table 6.1). RAI is dimensionless.

These extreme conditions are not favorable for rain-fed tropical crop production because extreme wetness is associated with flooding that destroys agricultural land while extreme dry conditions are associated with severe water deficits that cannot support agricultural production. Positive anomalies have their values above the average, and negative anomalies have their values below the average. Trend lines were fitted on the anomaly graphs to show changes in climate.

Food crop data were collected for maize, solanum potato, and beans for Oku (1982–2018) and Ndu (2000–2018). Rice production data were collected for Obang (1983–2018) and Ndop (1977–2018). These datasets were treated in anomaly form to show positive and negative changes with respect to variable climatic conditions. Food crop data was complemented by 597 household questionnaires administered throughout the three agroecological zones that make up the Bamenda Highlands to capture farmers' perceptions of changes in crop output with respect to climate variability and change.

Table 6.1 RAI classification

RAI range	Class description
≥3.0	Extremely wet
2.00 to 2.99	Very wet
1.00 to 1.99	Moderately wet
0.50 to 0.99	Slightly wet
0.49 to –49	Near normal
–0.50 to -0.99	Slightly dry
-1.00 to -1.99	Moderately dry
-2.00 to -2.99	Very dry
≤ -3.00	Extremely dry

Source: van Rooy 1965

Results and Discussions

Climate Variability and Change in the Bamenda Highlands

Climate variability and change is a global challenge facing socioeconomic systems, health, livelihoods, and food and water security. Climate variability has significant impacts on agrarian systems, especially in developing countries, which are dominantly rain-fed production systems (Tume and Fogwe 2018). Several indices are used to assess climate variability, especially in the tropical agrarian systems, such that the increasing trend of RAI implies a decreasing rainfall. This index was analyzed for ten stations across the Bamenda Highlands. Eight of the stations (Ndu, Tubah, MbawNso, Santa, Bamenda, Ndop, Oku, and Belo) have an increasing RAI (Figs. 6.2, 6.3, 6.4, 6.5, 6.6, 6.7, 6.8 and 6.9), while Jakiri has a relative constant RAI (Fig. 6.10), and that of Takui is decreasing (Fig. 6.11). A decreasing trend in RAI shows that rainfall is still reliable at this highland area.

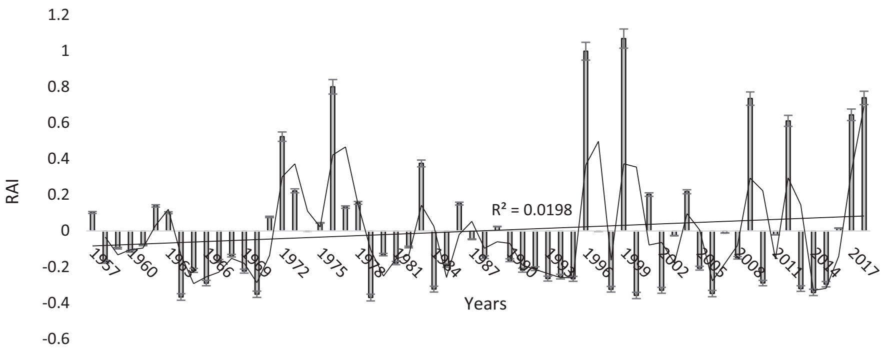

Fig. 6.2 Rainfall anomaly index for Ndu (1957–2018)

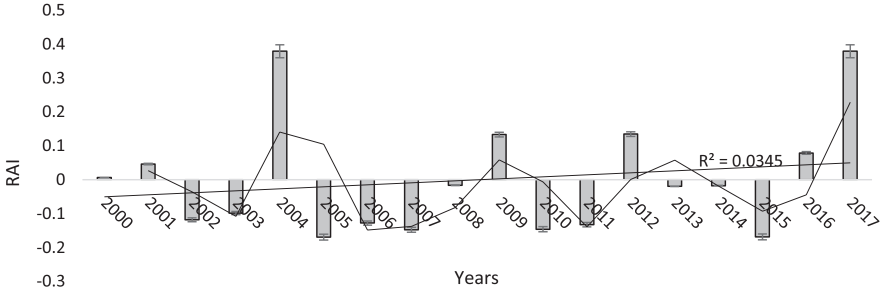

Fig. 6.3 Rainfall anomaly index for Tubah (2000–2017)

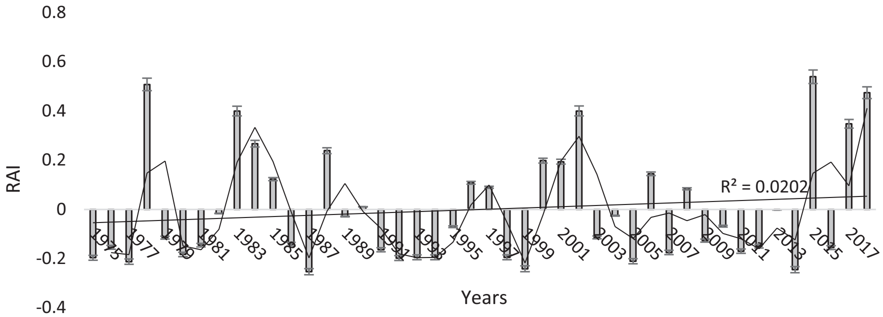

Fig. 6.4 Rainfall anomaly index for MbawNso (1975–2018)

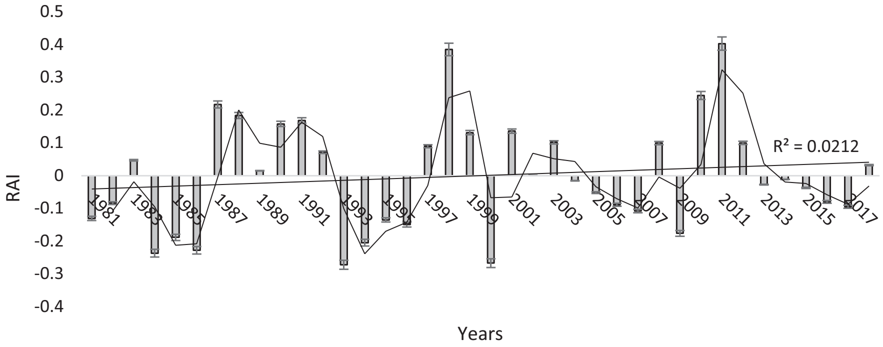

Fig. 6.5 Rainfall anomaly index for Santa (1981–2018)

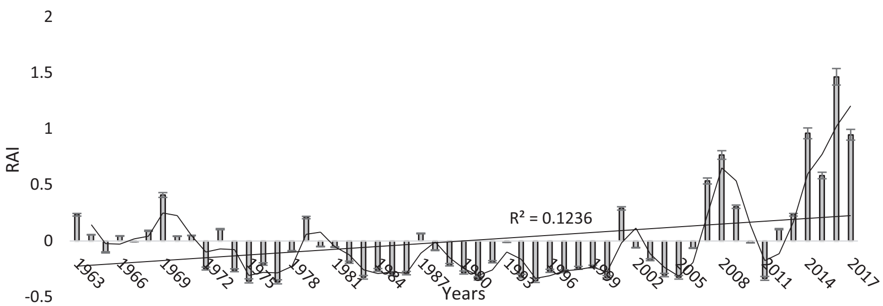

Fig. 6.6 Rainfall anomaly index for Bamenda (1963–2017)

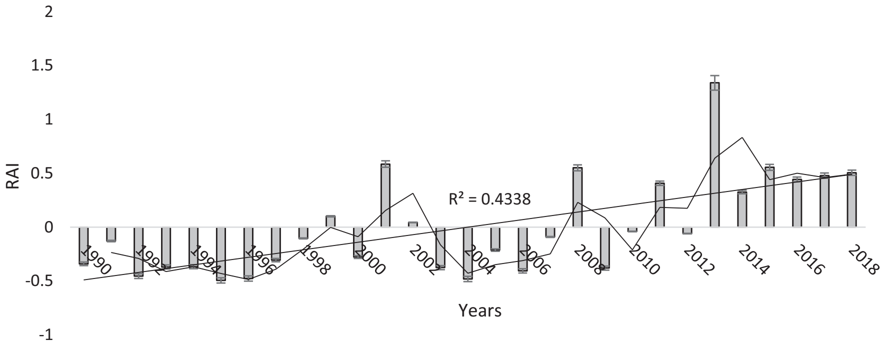

Fig. 6.7 Rainfall anomaly index for Ndop (1990–2018)

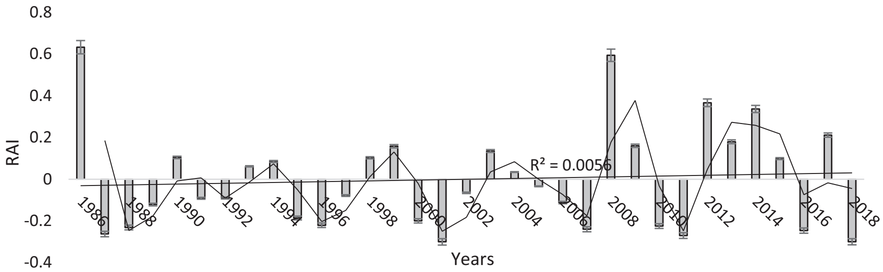

Fig. 6.8 Rainfall anomaly index for Oku (1986–2018)

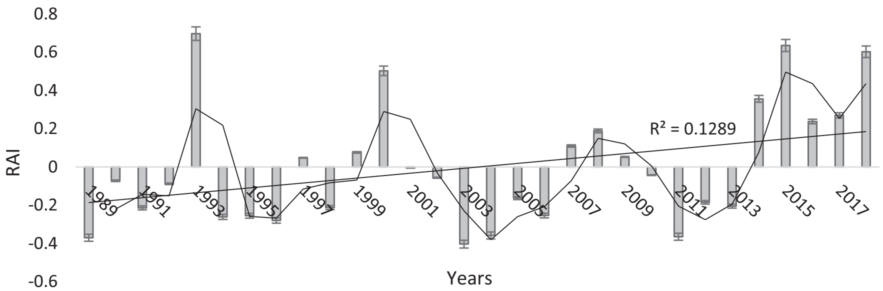

Fig. 6.9 Rainfall anomaly index for Belo (1989–2018)

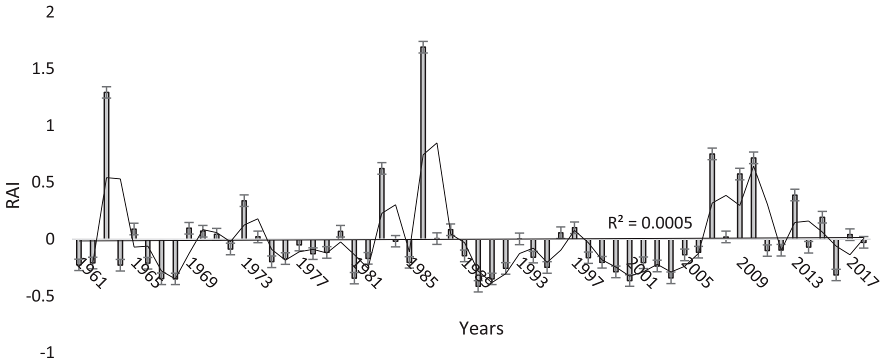

Fig. 6.10 Rainfall anomaly index for Jakiri (1961–2018)

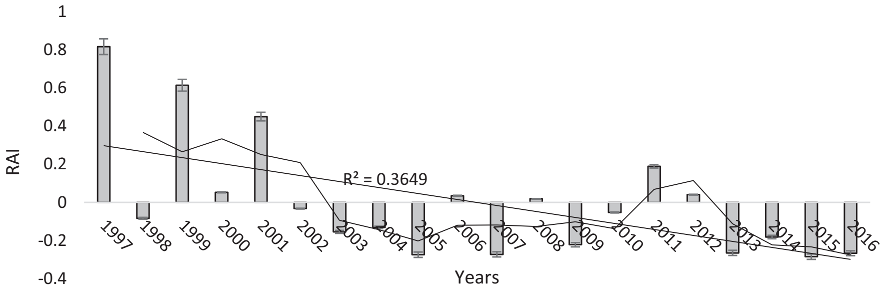

Fig. 6.11 Rainfall anomaly index for Takui (1997–2016)

In Ndu, which is located in the highland agroecological zone, the RAI ranges from -0.37 (near normal) to 1.07 (moderately wet conditions). The trend has been increasing.

In Tubah, located in the mid-latitude agroecological zone, RAI ranges from -0.17 to 0.38. These are near-normal conditions. Despite near-normal conditions, the trend has been increasing.

MbawNso, located in a lowland agroecological belt, has RAI values of -0.25 (near normal) to 0.54 (slightly wet). The trend has been increasing.

The Santa agrarian basin is located in the highland ecological belt. It has RAI values ranging from -0.27 (slightly dry) to 0.40 (near normal). The trend has been increasing.

Bamenda, located in the mid-latitude ecological belt, has RAI value of -0.37 (slightly dry) to moderately wet conditions. The trend has been increasing.

The Ndop plain is located in the lowland ecological zone, with RAI values ranging from -0.49 (slightly dry) to 1.34 (moderately wet). The trend has been increasing.

The highest altitude in the Bamenda Highlands is located in the Mount Oku region ($\approx$3011 masl). RAI values here range from -0.29 near normal) to 0.63 (slightly wet). The trend has been increasing.

Belo is a highland ecological zone with RAI values ranging from 0.40 (near normal) to 0.7 (slightly wet). The trend has been increasing.

Jakiri has varied topography with lowland, mid-altitude, and highland ecological conditions. The RAI values range from -0.41 (near normal) to 1.69 (moderately wet). The trend is near constant, with an increasing tendency.

Takui is one of the highland ecological zones of the Bamenda Highlands at an altitude of about 2800 masl. RAI values here range from -0.28 (near normal) to 0.82 (slightly wet). This is the only station with a decreasing trend.

All the stations located at high-altitude ecological zones have near-normal to slightly wet conditions, while mid-altitude zones have slightly dry to moderately wet condition. Lowland ecological zones on the other hand have slightly dry to moderately wet conditions. It is worth noting that extreme dryness and wetness are rare in the Bamenda Highlands. With the changing climatic conditions, RAI trends are increasing, suggesting that rainfall is gradually reducing across all the ecological zones.

Emerging Food Insecurity in the Bamenda Highlands

Agricultural production in the Bamenda Highlands is rain-fed. The Bamenda Highlands is ecologically diverse with a variety of food and cash crops (Fig. 6.12).

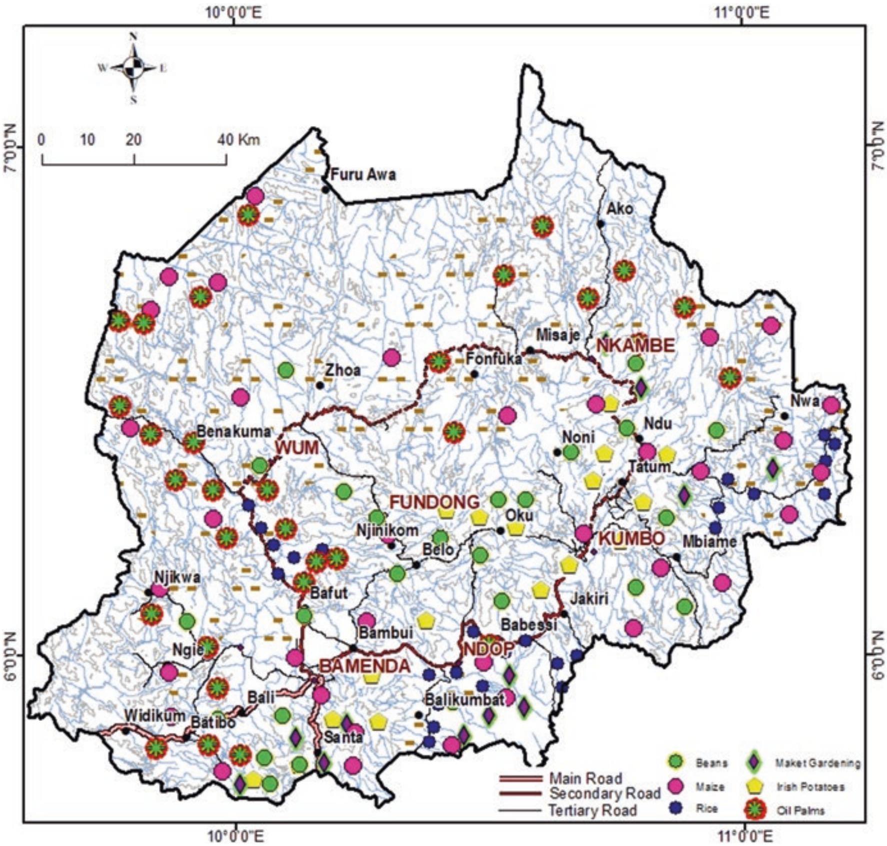

Fig. 6.12 Spatial distribution of crops in the Bamenda Highlands (Source: Fieldwork 2019)

The main food crops are solanum potato, beans, and maize, while cash crops are rice, groundnuts, palm oil, cassava, and market gardening crops. Maize, solanum potato, and beans have been reducing in Oku and Ndu, where considerable data was available (Figs. 6.13 and 6.14).

Maize yields dropped drastically during the 1982–1983 and the 1997–1998 droughts because rainfall was insufficient for successive growth during its vegetative growth period and the crops were bound to fail. This was the same with beans where during its pod formation period, there was not moisture sufficient to facilitate growth. Most of the bean plants were affected by the dwarf virus that is associated with high temperature. The potato plants all were wilted because of excessive evapotranspiration with no inadequate rains. Moreover, potatoes during their tuber enlargement need alternating sunshine and rainfall, but these years were characterized by less rainfall, so the tubers could not form properly. Again, 2002–2003 and 2007–2008 are all El Nino years. Besides, the heavy rains noticed during these years; they were accompanied by frequent wind storms and hail storms that destroyed bean flowers and leaves of crops during their pod formation season. The 2003, 2004, 2007, and

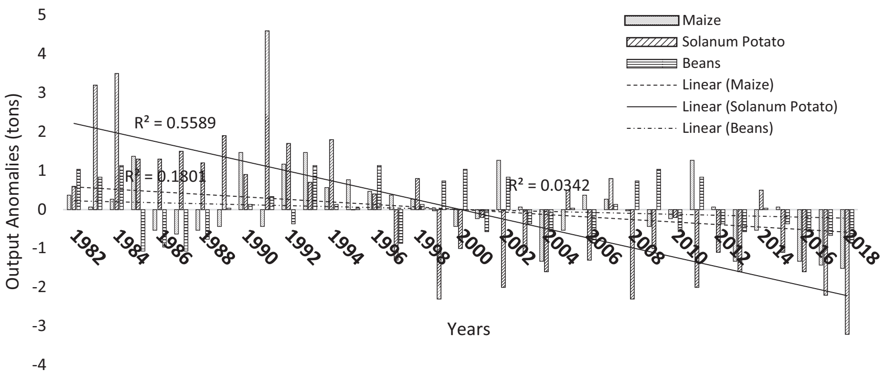

Fig. 6.13 Trends in crop output for Oku (1982–2018)

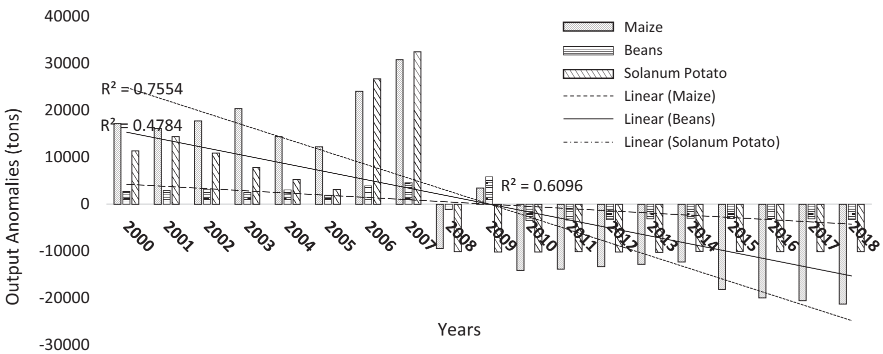

Fig. 6.14 Trends in crop output for Ndu (2000–2018)

2008 episodes are reflected in their harvest. These years corresponded with good yield from maize, but beans and potatoes, which are very sensitive to intense rainfall, experienced a reduction. A potato plant, for example, under high moisture content, is liable to late blight. Bean plants under such conditions are affected by aphids in the field. The 2007–2008 rains were so heavy up to periods of harvest that storage was difficult and most beans on the high-altitude areas rotted, thereby reducing yields.

Climate variability and change has already impacted and will further impact the agriculture sector and food production. Sensitivity to climate as well as several to other driving forces, especially from the economic and societal domains, will determine the future evolution of the sector. But climate influence must be considered as a first-order factor in the context of the enormous challenge of providing food for about 8–9 billion people by 2100 compared to the current 7.2 billion today (Zilberman 2018). Assessments of climate influence on crop functionality should consider stimulation of photosynthesis by the elevation of CO_2 atmospheric concentration. The direct influence of climate variations on crop function evidently involves temperature, the effects of which may be quite variable. Higher temperatures are generally favorable for growth in cold climates (except in extreme events) and generally unfavorable for warm areas. Further warming has increasingly negative impacts in all regions.

On the other hand, rainfall variability seriously modulates the potential changes in plant growth resulting from the effects of increasing temperatures. Tendencies toward drier conditions in some areas such as the West and Southern Africa may cancel, at least partially, the positive potential impact due to higher CO_2 or milder temperatures. Such combined climate influence leads to a variety of contrasted effects on crop production, depending upon the type, the geographical zone, and the level of adaptation. Farmers' perceptions were recorded on changing crop patterns (Table 6.2), with decreasing trends in food and cash crops.

Table 6.2 Perception of changes in crops output

Crops	Increase		Decrease		No change		% Change
	Freq.	%	Freq.	%	Freq.	%	
Maize	351	58.8	218	36.5	28	4.7	22.3
Solanum potato	91	15.2	415	69.5	91	15.2	-21.3
Beans	311	52.1	235	39.4	51	8.5	15.6
Groundnuts	173	39	196	32.8	228	38.2	2.5
Cassava	138	23.1	256	42.9	203	34	-13.4
Cocoyams	163	27.3	312	52.3	122	20.4	-9.2
Yam	103	17.3	123	39.2	260	43.6	-19.2
Tomatoes	254	42.5	116	19.4	227	38	6
Onion	150	25.1	188	31.5	259	43.4	-11.4
Soybeans	103	17.3	320	53.6	174	29.1	-19.2
Rice	95	15.9	320	53.6	182	30.5	-20.6
Vegetables	323	54.1	148	24.8	126	21.1	17.6

Source: Fieldwork, February 2019

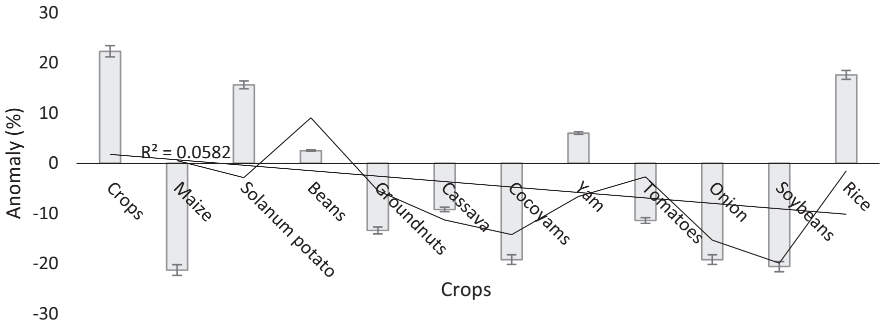

Fig. 6.15 Perceived crop variation anomalies

Solanum potato and coffee have the most perceived negative changes of -21.3% and -20.6%. Other crops with perceived negative changes are cassava (-13.4%), cocoyams (-9.2%), yam (-19.2%), onion (-11.4%), and soybeans (-19.2%) (Fig. 6.15).

These negative changes are attributed to changing climatic and environmental conditions. Crops are often attacked by blight and other pathogens during the tender growth stages, leading to plant mortality. Since the growing season of 2016, solanum potato has been devastated by blight. Irregular onset of rainfall has also negatively influenced coffee production. A strange disease has been devastating cocoyams since 2005. To have a clearer picture of perceived changes, crops have been grouped into food crops and cash crops. Farmers perceived that maize production is increasing. Solanum potato has been decreasing, while beans and vegetables have been increasing. Despite the increases in beans and vegetables, the cumulative trend of food crops is negative, with a coefficient of determination (R^2) of 0.0135 (1.35%). Cash crops on the other hand have been oscillating because of economic and environmental condition. Groundnuts have a positive change of +2.5%.

Cassava, cocoyam, rice, and soybeans have been decreasing because of their extreme susceptibility to climate variability and change. With no negative changes in vegetables, groundnuts, and onion, the cumulative perceived trend of cash crops has an insignificant positive R^2 of only 0.0002 (0.02%). These perceived variations in crop output have a direct link with temperature. The globally projected temperature increase by 1.4–5.8 °C, over the period 1990–2100 (Collier et al. 2008), will result in large changes in the frequency of extreme events which can have severe impacts on agriculture (Mathews et al. 2014). Increases in surface temperatures will increase soil temperatures which will in turn affect plant metabolism through the degradation of plant enzymes, limiting photosynthesis and affecting plant growth and yields (Campbell et al. 2011). Increases in soil temperature will increase potential evapotranspiration which causes damage especially to those crops with surface root systems which utilize mostly precipitation moisture (Collier et al. 2008). It increases leaf surface temperatures, hence affecting crop metabolism and yields making crops more sensitive to moisture stress conditions. Such crops include groundnuts, soybeans, maize, and fruit trees (Agba et al. 2017). Blanc (2012) revealed that crop yield changes in 2100 will be near zero for cassava, -19% to +6% for maize, -38% to -13% for millet, and -47% to -7% for sorghum under alternative climate change scenarios in sub-Saharan Africa.

The basic food stuffs on which people rely on daily have been declining in the Bamenda Highlands because food crop production systems are rain-fed. When there is hydrological, meteorological, or agricultural drought, threats to food security and crop failure will be evident. In Mbiame, the trend has taken a nose dive, and the climate continues to be very uncertain. This has to do with the timing of the onset of first rains and prevailing mild drought conditions throughout the growing season (Fig. 6.16).

The positive anomaly for solanum potato in Mbiame is because the dataset was documented prior to the great blight of 2016. Soybeans, groundnuts, rice, cocoyams, plantains, and onion have been decreasing in Mbiame. The general trend for crop production here has been negative, with a R^2 of 0.6654 (66.54%). This is an indicator of food insecurity. In the same vein, food crop production has been responding to climate variability, among other factors in Oku. Rice output has also been affected by variable climatic conditions. In Obang (Menchum Valley), the output is still slightly increasing (Fig. 6.17), while there has been a steep nose dive in the main production basin in Ndop (Fig. 6.18).

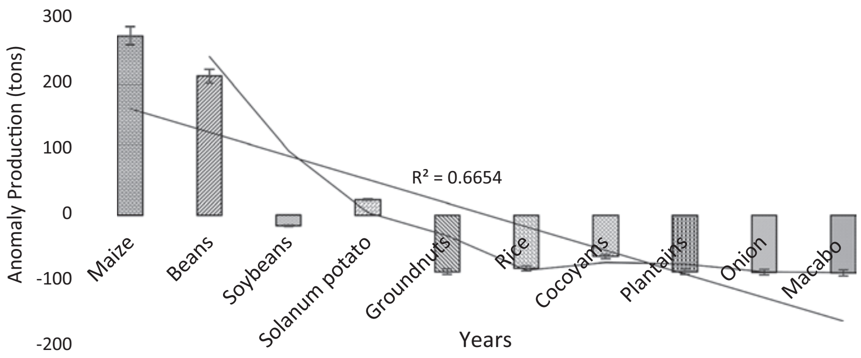

Fig. 6.16 Food crop production trend, Mbiame Sub-division (2006–2012). (Data source: Mbiame Council Development Plan, 2012)

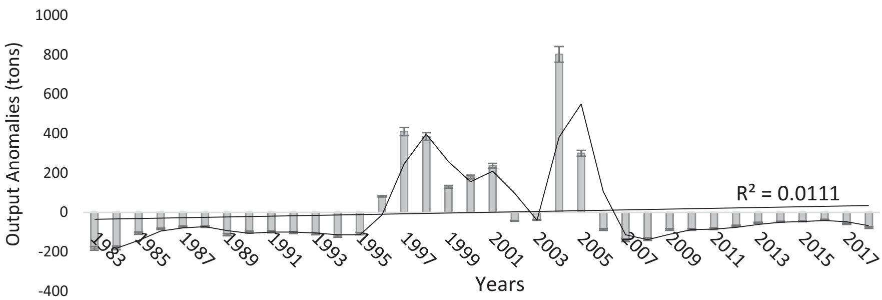

Fig. 6.17 Trend in rice output for Obang (1983–2018)

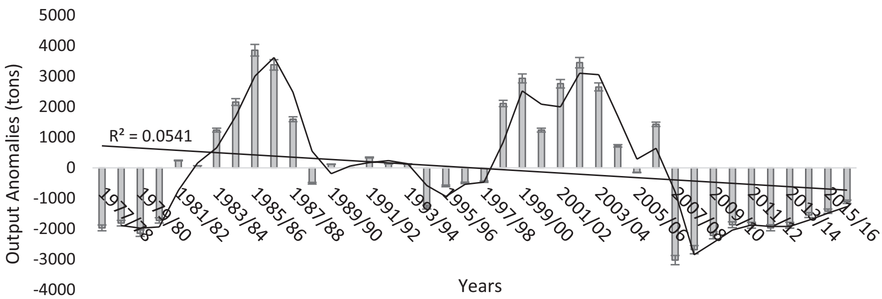

Fig. 6.18 Trend in rice output for Ndop (1977–2017)

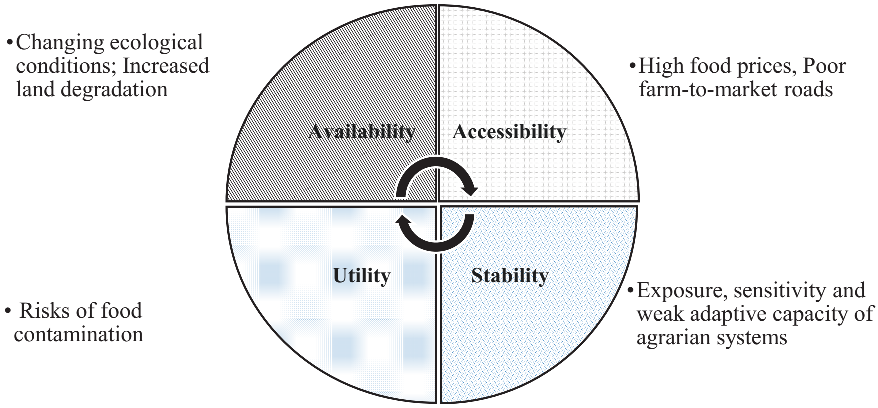

Fig. 6.19 The impact of climate change on food security dimensions in the Bamenda Highlands of Cameroon

The 1996 World Food Summit adopted the FAO definition of food security; thus, food security exists when all people, at all times, have physical and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life (Jafari and Jafari this volume). The definition encompasses four dimensions:

- Availability of sufficient quantities of food of appropriate quality, supplied through domestic production
- Access by individuals to adequate resources for acquiring appropriate foods for a nutritious diet
- 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
- Stability in the availability of and access to food, regardless of sudden shocks (an economic or climatic crisis) or cyclical events (seasonal food scarcity)

Climate variability and change is a threat to food availability, access, utilization, and stability. Ecological conditions in the Bamenda Highlands are favorable for diverse crops to be cultivated to meet the dietary needs of the population (Fig. 6.19).

Modification of agroecological conditions limits output and food availability, together with arable land degradation and a silent extinction of some food species like cocoyam which is a staple food in Ngemba land in Mezam.

Food is in abundant in interior villages and scarce in urban and semi-urban areas because of the poor state of farm-to-market roads to transport the produce. The poor transportation network, accentuated by heavy rains in the rainy season, limits physical accessibility. The transportation of food from areas of production to areas of consumption is interrupted. This leads to increase in food prices due to inadequate food supply in areas of high demand. Urban and semi-urban households with low income are the hardest hit because they cannot afford soaring prices. As such, food insecurity may eventually emerge in some areas because the excess food cannot be transported to areas of high demand. Again, extreme weather events such as recurrent floods and droughts increases food crop vulnerability to changing environmental conditions. Such physical shocks limit stability in crop output. This is not only in the Bamenda Highlands but in developing countries in general because they face a bleak future resulting from large-scale demographic, environmental, economic, and societal stresses. The links between food supply and demand are complex, with food supply affected by land and water, constraints, inadequate agrarian investments, trade, weather, and inadequate access to fertilizers and irrigation (FAO 2016). Food demand is affected by rising energy prices, population growth, globalization of food markets, changing diets, and the use of cropland for biofuel production.

Farmers' Adaptation Responses to Food Security Threats

The farmers most affected develop coping and adaptation strategies on crop production. These response strategies are perceived and applied in the three agroecological domains of the Bamenda Highlands. In the low-altitude domain, these are early planting, replanting, crop diversification, and the use of short season crops. In the mid-altitude domain, there is intensive use of organic manures, small-scale irrigation, water harvesting structures, chemical fertilizers, and early planting of crops. In the high-altitude domain, there is terracing, manure, fertilizer, agro-forestry, drought-tolerant crops, and crop diversification. Generally, early planting, crop diversification, increased use of manure and fertilizers, and the planting of crops with reduced growing degree days (GDD) were highly used by 70% of the farmers as crop production response strategies. The moderately adopted strategies here have been the practice of analogue forestry to curb adverse conditions of climate variability and change, the use of drought-tolerant crops, the implantation of water harvesting structures, irrigation, and terracing, among others. Based on the level of development and poor perception to climate change impact on food security, these adaptation responses are still far-fetched in some communities as most farmers have not fully adapted but are only resilient, a situation which has left behind footprints of food insecurity. Farmers are gradually embracing non-farm activities to supplement rural livelihoods such as petty trading and other climate smart activities like mushroom cultivation, apiculture, and aquaculture.

Farmers in the Bamenda Highlands are adapting to changing climatic conditions that play key roles in their decision-making, considering there are still a number of limitations to adaptation strategies. There is the urgency to mitigating greenhouse gas emissions from subsistence agriculture and other primary activities. This study has equally shown that there is a major improvement in knowledge and access to agricultural information among farmers with improved but inadequate access to media in the area through community radio stations (Tume et al. 2018). Households in some agro-zones observe positive changes in their farming practices largely because of the presence of some development NGOs such Green Care Association (GCA) in Shisong, Kumbo, Strategic Humanitarian Services (SHUMAS) with a climate-smart demonstration farm in Kumbo, and Rural Women Centre for Education and Development (RuWCED) in Ndop. Despite the presence of such development NGOs, agricultural productivity has continued to decline. There is, therefore, the need for a national climate change response strategy that will be put in place as a robust measure needed to address most, if not all, of the difficulties posed by climate variability and change to food and water security.

Conclusion

The current agricultural extension should target disaster risk preparedness and management to increase food security. Government must also look at the development of weather services for better and accurate weather information that farmers could use in their decision-making. The possible synergy between traditional and modern conception of climate change adaptation and mitigation could yield more benefit for better use of meteorological information. Encouraging farmers' education through extension services accessibility or adult education could help farmers in the adoption of new technologies and farming practices to deal with climate change effects to ensure food security. Farmers' adaptation response strategies should be improved by ameliorating the conditions affecting adaptation strategies like poor perception of changes in climatic patterns and receiving and documenting weather information, land tenure systems, and household characteristics. Global climate change has an adverse effect on agricultural production and will bring ever-increasing human population toward 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. This should be in line with Sustainable Goal 2 (SDG2) which aims to end hunger, achieve food security and improved nutrition, and promote sustainable agriculture. The target is to ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, maintain ecosystems, strengthen capacity for adaptation to climate change, extreme weather, drought, flooding, and other disasters and that progressively improve land and soil quality by 2030.

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Chapter 7
Building Capacities for Agricultural Disaster Risk Reduction in the Western Balkan Countries: The Case of Female Farmers in Serbia

Tamara van 't Wout, Anna Maria Augustyn, and Dragan Terzic

Introduction

The Western Balkan region is exposed to various natural hazards such as floods, landslides, storms, droughts, forest fires and earthquakes. With the changing climate, the occurrence and intensity of these hazards are increasing significantly. The adverse impacts on agricultural production and food security are clearly visible through extensive damages to agricultural equipment and facilities and production losses to the crop, livestock, forestry, fisheries and aquaculture subsectors. At the same time, the severity of these impacts is, among others, linked to environmental issues, e.g. the rapid dynamics in land use, land consolidation and abandonment, which are undermining diverse and healthy ecosystems that are in turn less climate resilient. Enhancing the policy and institutional capacities to adequately manage disaster risks is thus crucial to effectively address these challenges.

It is anticipated that the frequency and severity of hydrometeorological and climatological hazards, like floods, droughts, storms and changing seasonal patterns due to climate change, will present major challenges. The climatic changes that have already occurred have adversely impacted agricultural livelihood systems and related food security and nutrition (FAO 2015b). Moreover, drivers like population growth, rising incomes and urbanization will increase the demand for food and expect to lead to changes in lifestyles and consumption patterns, such as an anticipated decrease in grains and other staple crops, while vegetables, fruits, meat, dairy

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and fish will increase. At the same time, natural resources, including land, water, energy and biodiversity, are limited and in certain areas already degraded, which may further undermine the sustainability of food and agricultural production systems as well as constrain poverty alleviation and sustainable development in the coming decades (FAO 2009; Emadi 2019).

Smallholder farmers, herders, foresters and fishers, especially those in developing countries, are among the most vulnerable to natural hazards and climate change, as agriculture is among the most climate-sensitive sector (Squires, Gaur and Feng this volume). These people and their communities are often highly dependent on the sector and its activities for their food and nutrition security, income, livelihoods as well as overall well-being. It is estimated that the livelihoods of approximately 2.5 billion small-scale producers rely on the sector and related activities (FAO 2013). They manage over 80 percent of the world's estimated 500 million small farms and provide over four-fifth of the food consumed in developing countries (IFAD and UNEP 2013). In addition, they are also the custodians of these resources due to their role in food production as well as the management of natural resources.

An increase in frequency and severity of natural hazards is expected to magnify in the years to come (IPCC 2012). This means that floods and droughts will occur more often and affect more harshly rural populations. In order to manage their adverse impacts and improve preparedness, several concerted efforts have been thus undertaken by a range of international and national bodies. Most notable in this context, the Sendai Framework for Disaster Risk Reduction 2015–2030, provides for an intergovernmental agreement, with an aim to reduce disaster risk including economic, physical, social, cultural and environmental assets that belong to humans, their businesses, communities and countries (UNISDR 2015). Moreover, in certain geographic regions, such as the Western Balkan countries, additional provisions come with the preparations for the EU accession, i.e. introducing the acquis communautaire via enforcement of the EU Floods Directive (2007/60/EC) and related directives concerning environmental matters, e.g. the assessment of the effects of certain public and private projects on the environment (Environmental Impact Assessment – EIA Directive 2011/92/EU) and the assessment of the effects of certain plans and programmes on the environment (Strategic Environmental Assessment – SEA Directive 2001/42/EC) (European Parliament and the Council of the European Union 2001, 2007, 2011).

These legal documents and agreements promote improvements of the setting in which management of disaster risk is taking place. They are followed by the financial investments, stakeholder dialogues and a wide range of projects. They also require strengthening capacities of actors involved in their implementation at all administrative levels. In result, it is expected that a greater resilience could be achieved, i.e. the improvement of the system's ability, community or society exposed to hazards to 'resist, absorb, accommodate to and recover from the effects of hazard in a timely and efficient manner, including the preservation and restoration of its essential basic structures and functions' (UNISDR 2009: 24; Alexander 2013).

Objectives

The purpose of this study is to describe the overall context in which capacity building efforts for DRR are undertaken in the Western Balkan countries' agriculture, with special reference to Serbia. Our main rationale was to observe the changes that have occurred in the approaches to DRR in the recent years, with a special focus on the efforts for building capacities of the local communities. Our hypothesis was that the current efforts are still insufficiently targeted to the needs of the farmers, and their capacities to absorb the growing body of the DRR tools and management practices, notably those related with the emergence of the information and communications technologies (ICTs) and geospatial data, platforms and applications.

Methodology

In this study, we take a closer look at the various mechanisms which have been fostered in the Western Balkan countries with regard to improving their capacities in managing the disaster risk in the rural areas and the agricultural domain. While to date, most studies have been concerned with the capacity building of the administrative personnel and relevant governing bodies or NGOs, our study has a unique focus on the capacities or rural population and farmers in particular. The study included desk research combined with primary data from a questionnaire that was administered to female farmers and their communities in the rural areas of central and southern Serbia.

The study was conducted in the Fall of 2017 and reached out to 30 respondents who participated in the survey. It was conducted with the community of farmers who participated in the FAO regional disaster risk reduction (DRR) project implemented in 2016–2017. The initiative aimed at enhancing the resilience of farming communities to natural hazards, in particular floods, landslides and drought in the Western Balkan countries. The questionnaire was developed and administered among 30 female farmers in Serbia. The objective of this survey was to identify the impacts of different types of natural hazards on agriculture as well as gaps and needs for capacity building of female farmers to help to better plan and implement risk reduction measures in the agriculture sector.

Our survey was targeted to female farmers aged 30–67, all of whom were married, except one who was separated. The number of household members varied from 2 to 9, with an average of 4.2, of which only 11 and 9 of the 30 female farmers had girls and boys up to 18 years, respectively, with an average of 1.27 girls and 1.11 boys. In total, 7 participants (23%) indicated that they had completed primary school and 20 (67%) secondary school. Female farmers who participated in the survey were from the cities in the central and southern parts of Serbia, namely, Kruševac (villages: Bela Voda, Srnje, Vratarare, Jasika, Lazarica), Svrljig (Grbavče, Radmirovac, Izvor, Prekonoga, Lalinac and Svrljig) and Kraljevo (Ratina).

Some of the challenges in obtaining the data were related to, e.g. being able to interview the female farmers due to their busy schedules as well as gender-related issues, such as the decision-making power of the head of the household. Among some of the limitations and constraints included the limited number of respondents, which result in the findings providing only an insight into some of the issues, challenges and constraints with regard to capacity building, and access to and use of information and data to help reduce the adverse impact of natural hazards, such as droughts and floods, on agriculture in the central and southern part of Serbia. In this regard, the results can be seen as a case study with general observations. It is not valid for the entire region or country.

Disaster Risk Reduction

Disaster risk reduction is defined as 'preventing new and reducing existing disaster risk and managing residual risk, all of which contribute to strengthening resilience and therefore to the achievement of sustainable development' (UNISDR 2017). Following the devastating impact of the Indian Ocean tsunami in December 2004, the Second World Conference on Disaster Risk Reduction was held in Kobe in January 2005, which resulted in the establishment of the Hyogo Framework for Action (HFA) (2005–2015). The HFA aimed to reduce disaster risk and in particular build the resilience of nations and communities to disasters.

Its successor, the Sendai Framework for Disaster Risk Reduction (SFDRR) (2015–2030), was endorsed by the UN General Assembly following the 2015 Third UN World Conference on Disaster Risk Reduction (WCDRR). It aims to achieve 'the substantial reduction of disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries' (UNISDR 2015: 12).

The Sendai Framework has seven targets and four priorities for action aimed at preventing new as well as reducing existing disaster risks. Among the four priorities of action are (i) understanding disaster risk, (ii) strengthening disaster risk governance, (iii) investing in disaster risk reduction for resilience and (iv) enhancing disaster preparedness for effective response and to 'Build Back Better' in recovery, rehabilitation and reconstruction. The Framework establishes linkages with climate change with regard to, e.g. the exacerbation of disasters as well as one of the underlying disaster risk drivers.

The SFDRR fosters collaboration of the actors involved in managing disaster risks at all levels, with a special attention paid to strengthening capacities of the local communities and reducing their vulnerability. Coupled with growing concerns around the climate change and its increasing impacts on natural disasters, in this context, it is worth to highlight the community-based initiatives (CBIs) as a popular way to manage the responses at the local level (Allen 2006; Rojas Blanco 2006; Forino et al. 2018).

Disaster Risk Reduction in the Agriculture Sector

Agriculture is a highly climate-sensitive sector, and climate change will add another challenge to ensure sufficient agricultural production, due to the expected increase in the frequency and severity of extreme weather events, like floods, droughts and storms, which may lead to further damages and losses to crops, livestock, forestry, fisheries and aquaculture. Also, due to drivers such as population growth, rise in incomes and changing consumption and lifestyle patterns, there will be an increase in the demand for food, e.g. meat, dairy, fish, vegetables and fruits. At the same time, natural resources, including land, water, energy and biodiversity, are limited and in certain areas already degraded, which may further undermine the sustainability of food and agricultural production systems as well as constrain poverty alleviation and sustainable development in the coming decades (FAO 2009; Squires et al. this volume).

Reducing disaster risks and adapting to climate change for agriculture may include the application of on-farm practices. Technologies like conservation agriculture, agroforestry, using water more efficiently through drip irrigation systems and rainwater harvesting (FAO 2013). The use of local and hazard-resilient crop, livestock, fish and forestry varieties, such as drought-resistant or flood-tolerant varieties and breeds, as well as ensuring genetic diversity to enhance the efficiency, adaptability and resilience of production systems (Anya and Ayuk 2011; FAO, 2015a) can be beneficial. Moreover, it may also include reducing risks to natural and managed ecosystems (e.g. deforestation, ecosystem-based adaptation, biodiversity management, sustainable aquaculture, application of local and indigenous knowledge), risks of sea level rise (e.g. coastal defence structures, including dams and dikes but also mangroves, sustainable land use and planning).

Besides, it also includes interventions related to information systems to help to better understand disaster risks (e.g. disaster risk assessments, the use of climate and extreme weather information for farming decisions agriculture post-disaster damage and loss databases to help assess DRR investments and interventions) and early warning systems as well as shock-responsive risk transfer mechanisms (i.e. social protection and insurance schemes) and enabling legal, policy and institutional environment to support government planning, implementation, monitoring and evaluation of interventions as part of building resilience to climate variability and change.

For the agriculture sector, disaster risk reduction (DRR) and climate change adaptation (CCA) are closely linked as farmers and agricultural communities have for generations adapted on the basis of climate variability. There are many similarities between DRR and CCA as both aim to reduce risks and vulnerabilities from climate change and climate-related hazards. Although CCA focuses on hydrometeorological and climatological hazards as well as changes to the average conditions, DRR also focuses on all natural hazards, e.g. geophysical hazards. As a result, the area that is overlapping is sometimes indicated as ‘climate risk management’ as shown in Fig. 7.1.

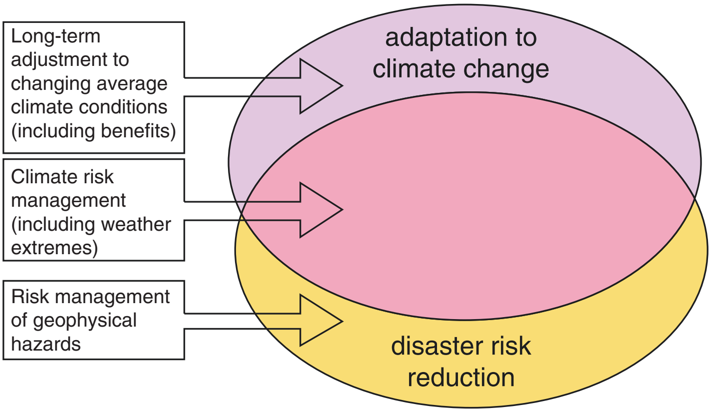

Fig. 7.1 Overlap between CCA and DRR (Source: Mitchell and Van Aalst 2008)

The importance of these linkages as well as the need for integration between DRR and CCA was also highlighted in the 2005 Hyogo Framework for Action as 'the integration of risk reduction associated with existing climate variability and future climate change' (UNISDR 2005: 11). Moreover, in the current Sendai Framework for Disaster Risk Reduction 2015–2030, it is stated that 'to incorporate DRR measures into multilateral and bilateral development assistance programmes within and across sectors, as appropriate, related to poverty reduction, sustainable development, natural resource management, the environment, urban development and adaptation to climate change' (UNISDR 2015: 25). In addition, the support for risk reduction actions, such as 'early warning systems, emergency preparedness, comprehensive risk assessment and management, risk insurance facilities, climate risk pooling and other insurance solutions' was included in the 2015 Paris Agreement (United Nations 2015: 4) as well as in the 2030 Agenda for Sustainable Development and its 17 Sustainable Development Goals. Various targets within the various Goals, e.g. Goal 1 on No Poverty, Goal 2 on Zero Hunger, Goal 11 on Sustainable Cities and Communities and Goal 13 on Climate Action, include targets related to DRR, CCA and building resilience to climate variability and change.

As a result, some of the risk reduction measures available to help agricultural producers reduce risks of climate-related hazards can also be used for adapting to climate change and as such are not different for the agriculture sector. Signs of convergence between DRR and CCA have been observed in, e.g. the agriculture and water and sanitation sectors (Tearfund 2008; Mitchell et al. 2010; CDKN 2014). In this regard, building resilience to climate-related hazards is a basis for both DRR and CCA, with DRR focusing on enhancing existing capacity in order to anticipate, resist, cope with and recover from the impact of hazards, while CCA is more concerned with future risks, thus trying to, i.e. address uncertainty/new risks (Tearfund 2008).

Capacity Building

The concept of capacity building has been central to practice of many donors, organizations and institutions involved in the disaster risk reduction and management (DRRM). While there is a lack of single definition, it is commonly narrated through the associated principles, processes and outcomes such as 'participation', 'empowerment' or 'helping people to help themselves' and strengthening civil society organizations (Eade 1997). Building upon these conceptual frames, the efforts of development agencies are thus oriented on strengthening the actors that are the end-users of development interventions or have to deal with those directly.

In the recent decades, one of the main reasons behind the growing focus on capacity building as a solution to existing challenges such as disasters is the tendency to delegate the power from the central to local level (multilevel governance) and the subsidiarity principle (Berger and Neuhaus 1977; Stephenson 2013). Moreover, it has been the core imperative for transformation of the governing structures and a precondition of the EU accession in the aspiring countries (Bache 1998; Bailey and de Propris 2004). In line with this, the complex EU acquis[1] needs to be translated into the settings of interconnected institutions and actors that deliver the services in a synergetic way.

Frequently, cascade approaches are promoted, where capacity building is offered to the intermediary bodies which deliver further capacity building to other ones. In addition, people-centredness, women empowerment, sustainability and resilience are referred to in this context. An increased participation of citizens in governance is expected to improve as a result of capacity building efforts (Cairns et al. 2005; Cuthill and Fien 2005). Communication between the actors and learning processes is also at the centre of those approaches. They build upon various streams of knowledge, especially those from psychology and education (Lewin 1946; Freire 1970; Pluskota 2014). Action research and learning are the goals and ways triggering the positive transformational process towards (Fals-Borda 1984; Thompson and Scoones 1994; Ison and Russell 2000; McCall and Peters-Guarin 2012; Kagawa and Selby 2012).

In the context of agriculture, DRRM involves a wide range of tools and methods. Specific attention is paid to building capacities of farmers and agricultural extension services, which are in the frontline of communication with farmers and risk-prone communities and experiential (or learning-by-doing) approaches (Altieri 2004; Van der Wal et al. 2014). One of the most popular practices in the developing context is the farmer field schools (FFS), through which the disaster risk reduction good practices and technologies for agriculture can be demonstrated, validated and upscaled. This approach was developed by FAO and partners nearly 25 years ago in Southeast Asia as an alternative to the prevailing top-down extension method (Feder et al. 2003; Van den Berg 2004; Tripp et al. 2005).

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[1] **Acquis** is a French term **meaning** 'that which has been agreed'.

In a typical FFS, a group of 20–25 farmers meet once a week in a local field setting and under the guidance of a trained facilitator. They use control plots where the conventional practices are implemented as well as test plots to compare the differences in terms of, e.g. yields, income generation, ability to reduce the adverse impacts of natural hazards, and ability to reduce/remove greenhouse gas emissions. They experiment with and observe key elements of the agroecosystem, exchange knowledge and information, discuss and plan.

The learning-by-doing approach promotes farm-based experimentation, group organization and decision-making as farmers are able to see for themselves if the practice works, which creates ownership that can lead to farmers replicating and upscaling the practices in their own plots or convincing other farmers to do the same. This is also encouraged through the organization of field day to show local politicians, government agricultural workers and other farmers what they are doing. Exchange visits with other FFS are also encouraged, and the season-long approach helps build stronger social ties, also between farmers, extension workers and researchers, that carry on after the initial FFS. Ideally, the same practices should be tested and validated through, at least three seasons, to ensure that these are effective. FFS can be a powerful methodology to facilitate change and adoption of different practices and technologies. At the same time, it often leads to positive improvements in the farming systems, such as increasing farm productivity (Godtland et al. 2004).

Gender Inequality and Capacity Building

Women play a significant role in the agriculture sector. Approximately 43% of the global agricultural labour force in developing countries are estimated to be female (FAO, 2011a). Even though women's contribution to the sector varies across and within countries, in general, the labour burden of rural women exceeds that of men, including a larger share of unpaid household tasks with regard to preparation of food and collection of water and fuel (Elham 2019).

Women and men are affected by the same risks differently, but they also face different types of risks, as a result of various factors, related to, e.g. economic vulnerabilities (i.e. differences in wages), culturally specific gendered norms (i.e. different household tasks), mobility constraints and language barriers. The economic and social gender-specific vulnerabilities are often interlinked and may lead to chronic poverty and higher vulnerability levels, especially to external shocks and stresses, such as extreme weather events and climatic changes.

In many developing countries, women still own fewer assets (i.e. land, livestock) than men as well as have limited access to inputs, such as seeds, fertilizer, labour and finance as well as access to information, knowledge and capacity building trainings. Some of the various challenges and constraints related to this include often higher illiteracy rates among women than men as well as limited access to information that is disseminated using information and communications technologies

(ICTs) as they are less likely to own a mobile phone or have access to a radio as well as general lack of Internet facilities and access to Internet. This may also limit women's ability to access early warnings as well as (i.e. seasonal, monthly) climate forecasts for agriculture. Women may be involved in other household-related responsibilities and tasks when climate information is transmitted. It is highly important that women have access to these early warning alerts and climate forecasts, as they have, particularly in developing countries, a substantial role in agricultural production as well as family nutrition (World Bank n.d.; McOmber et al. 2013; Oedoemelan 2016; IFLA 2017).

In this regard, also ensuring that women have access to agriculture-specific knowledge and trainings on, e.g. resilient and sustainable agricultural practices and technologies, is highly important, as in general they have very limited access to extension services compared to men. It is estimated that globally women only receive 5% of agricultural extension services (UNDP 2016). Extension services as well as the promoted practices and technologies should also address women's needs. Farmer field schools (FFS) in Kenya, Uganda and Tanzania, where women farmers participated, also focused on vegetable gardens and seed nurseries, postharvest management and storages as well as integrated nutrition and health with agriculture. As a result, women were able to obtain valuable knowledge for contributing to the household's and communities' food and nutrition security (ODI 2009; FAO, 2011b).

Serbia's Natural Hazards and Climate Change in Agriculture

Serbia is highly prone to natural hazards. According to the INFORM Risk Index of 2018,[2] the country is exposed to natural hazards, such as (flash and river) floods, storms, drought, landslides and earthquakes, and biological hazards, like plant and animal pests and diseases, which may lead to substantial damages and losses to animals and people. As shown in Fig. 7.2, Serbia is among the most exposed and vulnerable, although Bosnia and Herzegovina is ranked the highest among the Western Balkan countries with regard to natural hazards and humanitarian crises and disasters.

In Serbia, floods have occurred the most frequently during the 1990–2014 period, followed by extreme temperatures and earthquakes as shown in Fig. 7.3. The valleys with the larger water courses and where settlements, farmland, infrastructure and industry are located are more prone to inundation, in particular in the Vojvodina region as well as along the rivers of the Sava, Drina, Velika Morava, Juzna Morava and Zapadna Morava. These floods in the major river basins are usually the result of

[2] This index measures the risk of humanitarian crises and disasters through 50 different indicators for hazards and exposure, vulnerability and lack of coping capacity, among others. The index consists of data and country profiles for 191 countries and is free and publicly available. For more information, see http://www.inform-index.org/Countries/Country-Profile-Map.

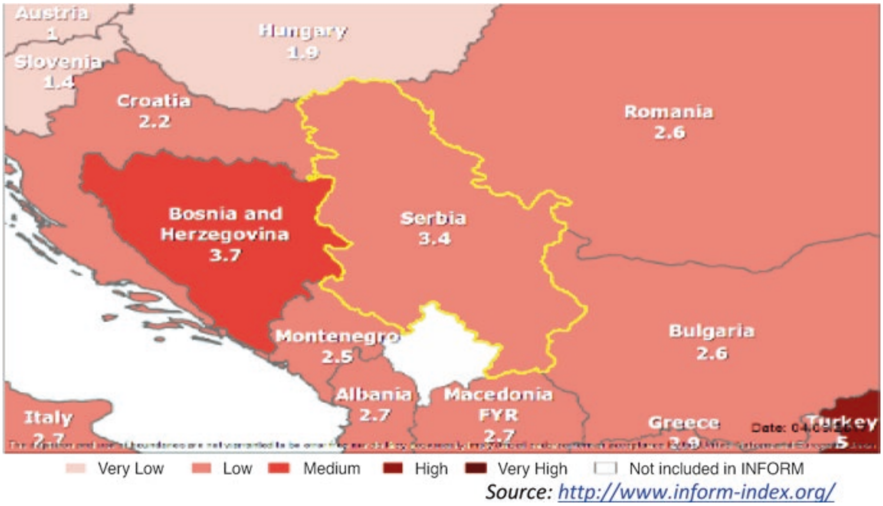


Fig. 7.2 INFORM Risk Index of 2018 for the Western Balkan region. (Source: http://www.inform-index.org/)

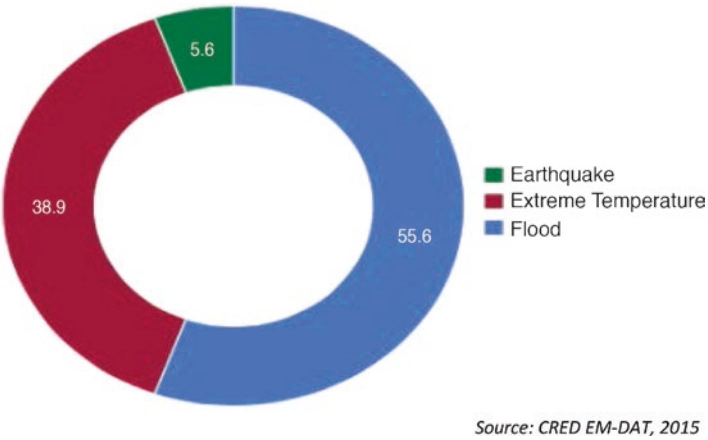


Fig. 7.3 Frequency in percentage by type of natural hazard in Serbia, 1990–2014. (Source: CRED EM-DAT 2015)

longer periods of extensive rainfall and/or the intensive melting of snow, while flash floods in the smaller river basins and generally due to short intensive rainfall as a result of summer storms. Moreover, factors, like the lack or limited maintenance of embankments and/or flood defences as well as debris and sediments blocking river, drainage or diversion channels, contribute to the extent of inundation.

Past disasters have substantially impacted the agriculture sector, for instance, the severe rainfall that occurred during the months of April and May 2014, which resulted in the worst flooding in over a century and affected 24 municipalities. The total damages and losses to all sectors were estimated at EUR 1.5 billion, of which 15% or EUR 228 million was the impact to the agriculture sector. It was calculated that EUR 107.9 million and EUR 120.1 million were estimated damages and losses, respectively, to the sector. In terms of recovery and reconstruction needs to the sector, these were estimated at EUR 152.1 million, of which EUR 40.8 million for recovery and EUR 111.4 million for reconstruction (UN/EU/World Bank Group 2014).

The impacts of droughts on the sector is also significant. Especially the areas in the eastern part of the country as well as in the Pannonian Basin in the north are drought-prone. During the 1991–2010, 1992, 1993, 1998, 2000, 2003 and 2007 were years that were extremely dry (WMO/UNCCD/FAO and UNW-DPC 2013). While 2 years later in 2009 and particularly between April and September, Sremska Mitrovica towards the north-west as well as Central Serbia was affected by drought (Duričin and Bodroža 2013). Again, during the Summer of 2012, a drought negatively affected the sector with estimated losses to agricultural production of approximately USD 2 billion, e.g. corn (USD 1 billion), sugar (USD 130 million), soybeans (USD 117 million), fruits and vegetables (USD 100 million), sunflowers (USD 55 million) and other agricultural crops (USDA Foreign Agricultural Service 2012).

Climate change projections estimate the increase in frequency and intensity of natural hazards, such as floods and droughts, as well as in terms of scope and duration (IPCC 2012). In addition, it is anticipated that there will be increased exposure to multiple and compound climate-related risks between 1.5 °C and 2 °C of global warming, and these risks are likely to impact, e.g. food security, livelihoods, water supply, health, human security and economic growth (IPCC 2018).

In Serbia, during the 1960–2012 period, a rise in the daily mean temperature has been observed, as well as in the daily minimum and maximum temperatures with an estimated average rise of 0.3 °C annually and per decade. In addition, eight out of ten hottest years ever were reported after 2000. In general, an increase in precipitation has also been observed, although with different distribution intensities during the year. This included an increased number of heavy rainfall events, although the total annual precipitation was relatively small (Ministry of Environmental Protection 2017).

It is anticipated that climate change will result in a rise in temperature by 0.5–0.9 °C and 1.8–2.0 °C, respectively, under A1B scenario for 2011–2040 and 2041–2070. While under the A2 scenario, the expected temperature will increase by 0.3–0.7 °C in 2011–2040 and 1.6–2.0 °C in 2041–2070. Towards the end of the century (2071–2100), the predicted rise is 3.2–3.6 °C under the A1B scenario and 3.6–4.0 °C under the A2 scenario. In terms of precipitation, under the A1b scenario, the anticipated changes vary from +5% to -20% and from +20% to -20% under the A2 scenario. The decrease in rainfall is especially predicted during the summer months. Frost days are expected to become rare towards the end of 2100, together with longer periods of droughts predicted to last for over a month under both scenarios (Ministry of Environmental Protection 2017).

It is expected that agricultural production of various crops will be impacted by climate change due to changes in temperature and precipitation. For instance, during the 2001–2030 period, maize is predicted to mature 7–13 days earlier, although for soybean and wheat, no change is expected. However, during the 2071–2100 period, both maize and soybean are anticipated to flower more than 2 weeks earlier, while full maize and soybean maturation may happen up to 2 months and 2 weeks earlier, respectively, which can substantially impact quantity as well as quality of yield. As a result, for some crops, yield reductions are estimated, such as -10% for winter wheat in the southern area of Serbia expected for the 2071–2100 period and soybean yield changes from -14% to 20% for the 2071–2100 period in the northern and southeastern areas of the country (Ministry of Environmental Protection 2017).

Serbia's Agriculture Profile

The agriculture sector is an important sector for the economy of Serbia, as it accounts for approximately 8.2% of its gross domestic product (GDP) (World Bank data 2009[3]). In certain regions of the country, the sector is a core economic activity for people's livelihoods. In general, the areas in the south and southeast are the poorest, whereas the Vojvodina region in the north is more endowed in terms of fertile soil and where the large agricultural commercial companies and cooperatives are located with sizes varying from 50 to 2500 hectares (FAO 2009[4]). In general, the country has favourable climatic conditions as well as extensive water resources for its agricultural production. In addition, over half of the country's surface is agricultural land (4,867,000 hectares), of which 71% (3,437,000 hectares) is utilized agricultural land (Ministry of Agriculture and Environmental Protection 2014). Among its primary export products include. maize, wheat, apples and frozen raspberries. It is estimated that these products make up around 21% of its national exports (USDA 2015[5]).

It is estimated that 40% of its total population reside in rural areas, where one in every five persons is over 65 years, while in the southern and eastern parts of the country, it is calculated to be one in every four. Around one-third of the female population in the rural areas did not attend any school or unfinished or finished primary school (Ministry of Agriculture and Environmental Protection 2014). While it is estimated that approximately two-thirds of these people fully or partially rely on the agriculture sector and its activities for their livelihoods, according to official statistics, about 20% of the working population is employed in the sector (Republic of Serbia 2014). The country's unemployment rate is estimated at 12.8% in 2018, while its youth unemployment rate is calculated at 29.7% in 2018 (Eurostat 2019).

[3] World Bank data, 2015.

[4] FAO data, 2009.

[5] USDA, 2015.

Findings from the Survey

While the survey respondents were 30 female farmers, a relatively small group, it was challenging to perceive them as a homogenous group. On the contrary, they were very diverse in terms of land ownership, sources of incomes, employment, agricultural production and participation of their farms in the market.

With regard to land ownership, 20% totally owned the land, 10% owned more than half the land, 10% owned less than half the land, while the majority (53%) did not own the land. Of those female farmers who indicated that they owned the land, 47% indicated that their husbands actually owned the land and 27% indicated that they themselves owned it. With regard to average size of the land, it was calculated at approximately 1.8 hectares.

The majority of the female farmers were an unpaid family worker (57%), an employee (37%) or an employer (3%). For the majority of the participants (53%), farming was not the main source of income, although for 43% it was. Moreover, for 90% of the participants, who were engaged in food production for consumption, and at the same time, 67% are also engaged in food production for the market, but 30% said they were not.

In terms of agricultural production, 47% of the survey participants were engaged in vegetable production, including tomato, cucumber, paprika, etc., while 10% was engaged in crop production, like maize and winter wheat production and livestock production, such as poultry and pigs, while 50% were engaged in a combination of two or three. For instance, two participants combined both vegetable and crop production, while one participant combined vegetable and livestock production and another one combined vegetable, crop and livestock production (Fig. 7.4).

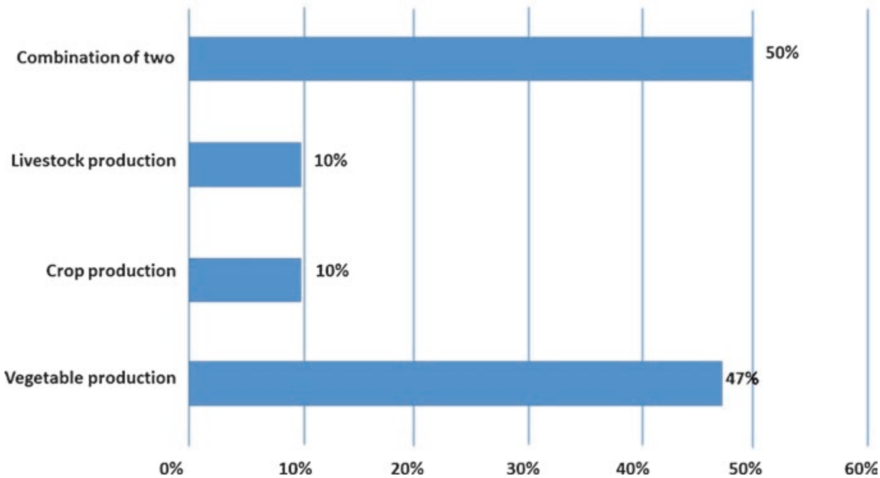


Fig. 7.4 Engagement of female farmers involved in the type of agricultural production in Serbia (%). (Source: Agrolink 2017)

All female farmers who participated in the survey were engaged in various agricultural activities, and the extent varied per type of activity. For instance, most of them were involved in seeding (70%), manual removal of weeds (60%), processing and storage (47%), and animal management (43%) as well as to a lesser extent involved in preparation of land and harvesting (23%) and transportation (10%) (Fig. 7.5).

Survey respondents were asked about the extent to which various natural hazards could cause damage to their agricultural production. As shown in Fig. 7.6, the impact of drought is considered high and very high in terms of resulting in damage and losses to agriculture. While flood, storm winds and excessive precipitation may damage some but not all farmers' crops and livestock. For most participants, landslides are viewed as for the most part not adversely impacting the sector.

Despite that natural hazards can cause significant damage and losses to crops, livestock, forestry, fisheries and aquaculture, there are also many other factors that may constrain the development of the farm. For instance, the participants viewed, among the limiting factors, the lack of working capital, the lack of labour among the most important factors as well as, to a lesser extent, natural hazards, lack of market, low profit in production and poor soil quality. While the lack of knowledge and inability to make and implement decisions were seen as less limiting, opinions were divided with regard to lack of land and lack of machines and equipment as shown in Fig. 7.7.

When the surveyed female farmers have a problem related to agricultural production, they turn the most to other trusted producers, as well as to some extent read relevant books/magazines, use the Internet or consult with extension service officers, but not many turn to research for support (Fig. 7.8). With regard to the method of information that they use the most, similar answers are provided, but also including watching relevant TV shows as a source of information (Fig. 7.9).

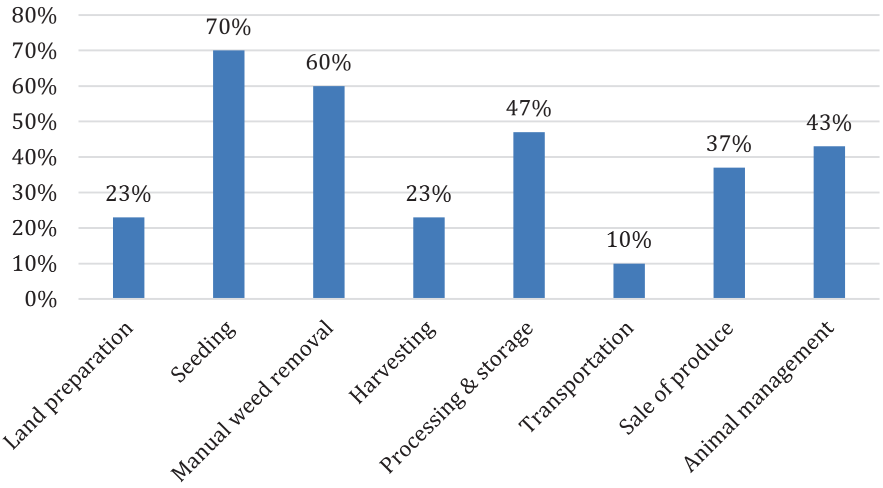


Fig. 7.5 Engagement of female farmers in the type of agricultural activities in Serbia (%). (Source: Agrolink 2017)

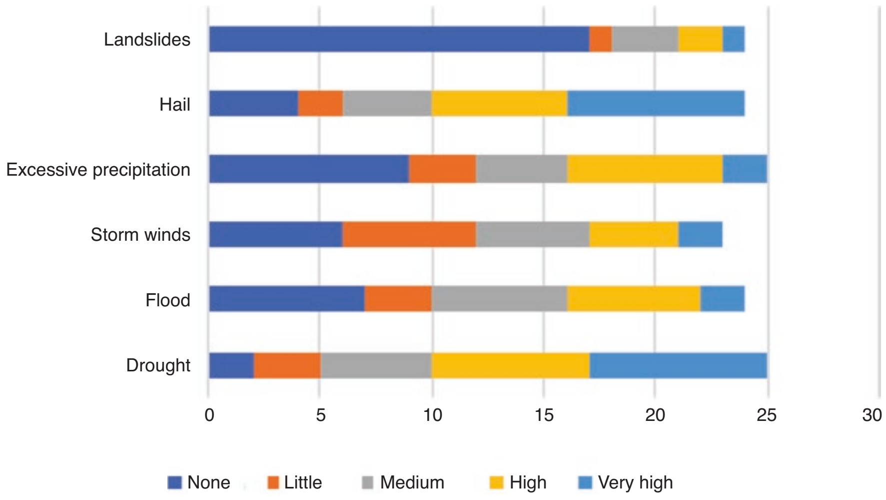


Fig. 7.6 Overview of the types of natural hazards that can cause damage to agricultural production in Serbia (number of respondents). (Source: Agrolink 2017)

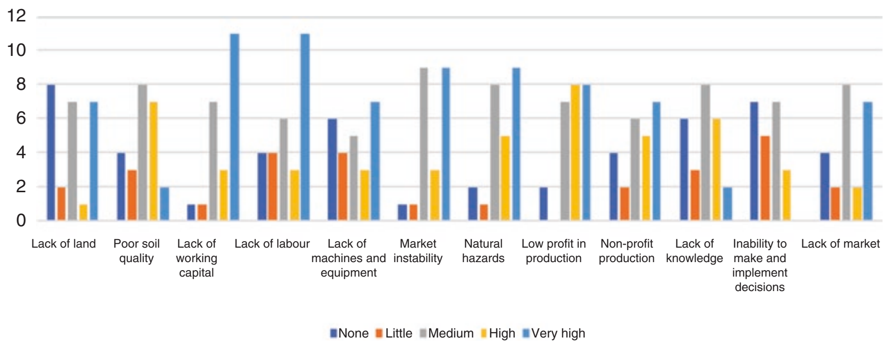


Fig. 7.7 Overview of the limiting factors constraining development of the farm in Serbia (number of respondents). (Source: Agrolink 2017)

A survey question was also included on the various obstacles that female farmers face when launching new agricultural production in order to better understand their challenges and risks. Establishing a new type of agricultural production can also help to diversify existing production, thereby mitigating the risk of total or partial production failure due to, e.g. extreme weather events, like floods, droughts and storms. Among the obstacles considered include the lack of subsidies and favourable loans as well as lack of workforce, the fear of failure, lack of knowing what is profitable as well as insufficient professional knowledge and skills for new production. However, insufficient professional institutional support and distance and poor traffic connections with other cities are not extensively viewed as obstacles (Fig. 7.10).

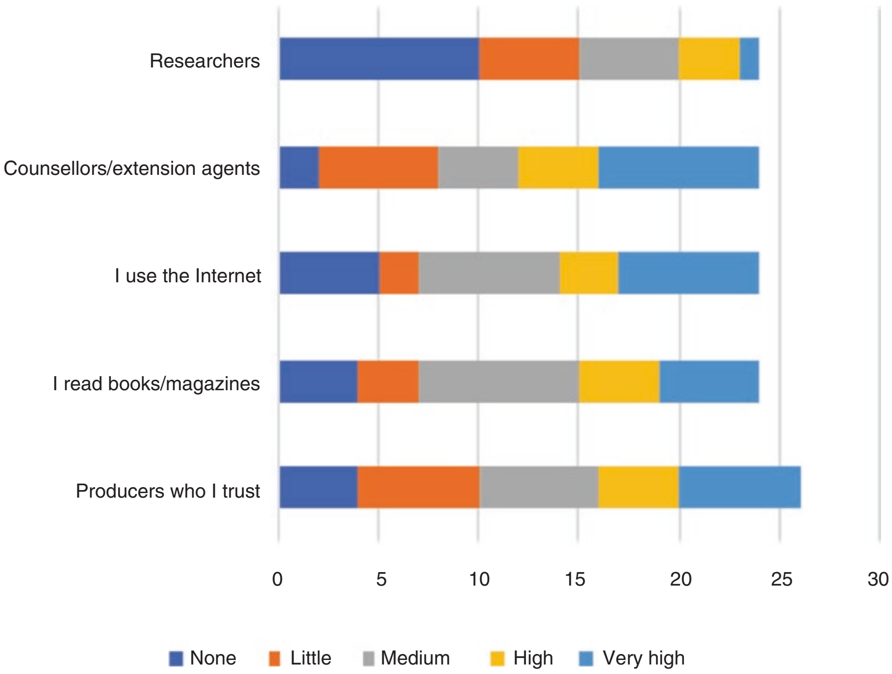


Fig. 7.8 Who do you turn to for help most when?

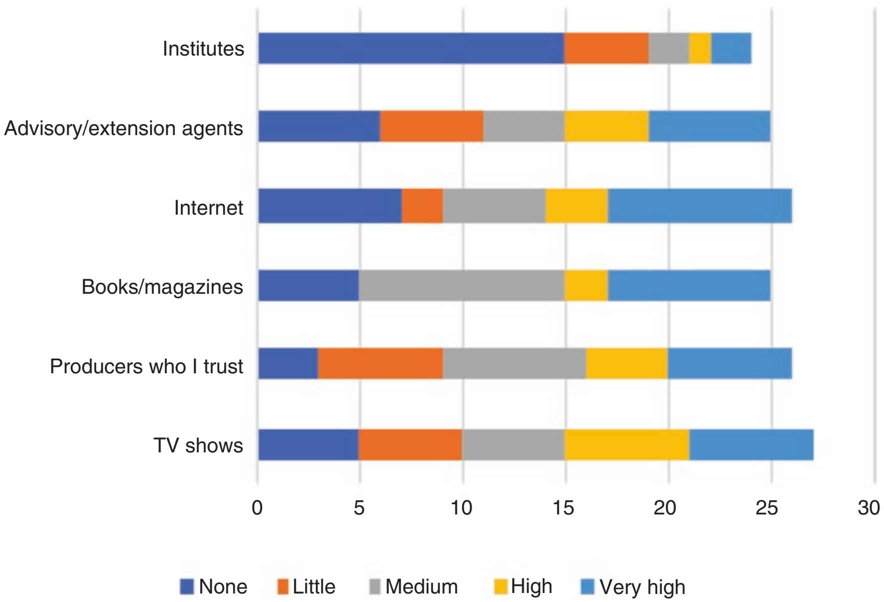


Fig. 7.9 What method of information do you use most, you have a production related issue (number (number of respondents)? respondents)? (Source: Agrolink 2017)

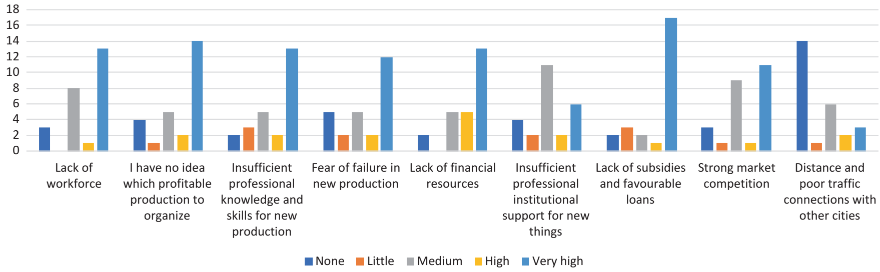


Fig. 7.10 Possible obstacles to launching of new agricultural production in Serbia. (Source: Agrolink 2017)

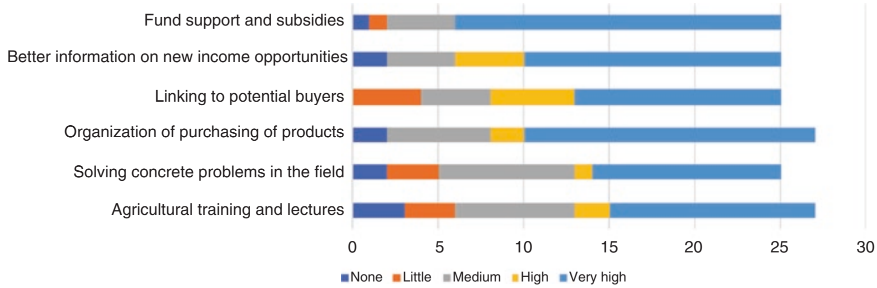


Fig. 7.11 What kind of support would to help overcome these obstacles? (Source: Agrolink 2017)

Since the access to financial resources was indicated as one of the primary obstacles, fund support and subsidies is therefore considered as a way to address this constraint as well as some market-related issues, such as better information on new income opportunities, linking to potential buyers and organizing the purchase of products. Capacity building-related support is also viewed as important, including agricultural training and lectures, as well as support to help solve concrete problems in the field as outlined in Fig. 7.11.

In terms of challenges that the participants face when attending trainings, workshops or meetings, 27% said that they lack time as a result of farm/employment obligations, followed by 23% who are not informed about these capacity building events, while 7% indicated that they did not attend and some did not have the opportunity to go to the training, and some specifically said that this was due to the lack of permission from their husband (Fig. 7.12).

Most of the survey participants (43%) indicated that they never received any information or advice from extension service on agricultural production, while 23% and 27% said that they do receive frequently and a few times, respectively, and 7% said they only once received information or advice. In addition, 16% said that usually other family members deal with extension, 13% said that no one contacted them and 3% indicated that they do not see how these advisory services could be useful to them (Fig. 7.13).

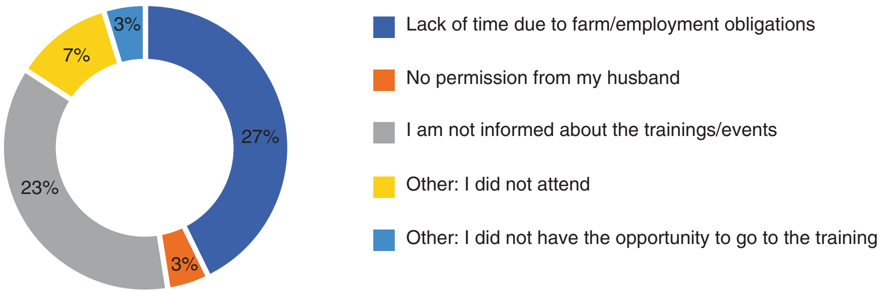
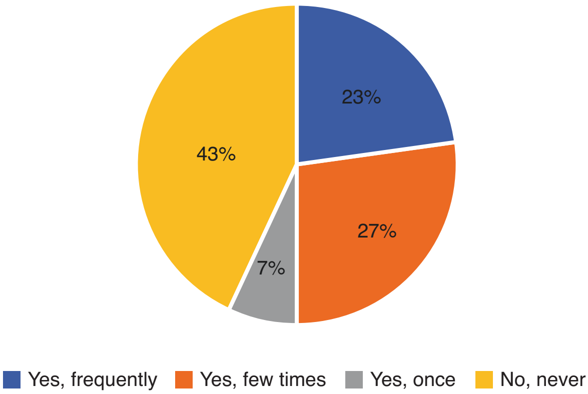


Fig. 7.12 What challenges did you face when attending trainings, workshops or meetings in Serbia (%)? (Source: Agrolink 2017)

Fig. 7.13 Have you ever received any information or advice from extension service on agricultural production in Serbia (%)? (Source: Agrolink 2017)



Conclusions

Serbia is prone to various types of natural hazards, e.g. floods, landslides, droughts, storms and wildfires. With climate change, these natural hazards are expected to increase in frequency and severity. Agriculture is one of the most climate-sensitive sectors and is anticipated to be adversely impacted, through damage and losses to crops, livestock, forestry, fisheries and aquaculture, by climate-related hazards. The sector and its related activities are an important source of food and income for the majority of people, in particular those who reside in rural areas. Within the context of climate change, mitigating the negative effects of extreme weather events on agriculture is essential.

Female farmers form a substantial part of the agricultural workforce in Serbia, especially with regard to small-scale vegetable production in their gardens. In the presented case study, women are involved in various agricultural activities, e.g. seeding, manual weed removal, animal management, processing and storage and to some extent selling of produce, land preparation, harvesting and transportation. Female farmers are particularly vulnerable to adverse impacts of natural hazards (especially drought, but also floods, storm winds and excessive precipitation) on their agriculture-related activities. Even though natural hazards can lead to significant damage and losses to crops, livestock, forestry, fisheries and aquaculture, other factors also constrain the development of their farms, including issues related to lack of or limited financial resources, lack of labor, lack of markets and poor soil quality.

From the case study findings, it has become apparent that for access to information, knowledge and capacity building activities, the majority of the female farmers surveyed would turn to other trusted producers and less to reading relevant books/magazines. Use of the Internet or consulting with extension service officers, while not many turn to research for support. Among the obstacles encountered when establishing new agricultural production were more related to lack of or limited financial resources, lack of labour and fear of failure, while insufficient professional knowledge and skills for new production were not extensively viewed as obstacles. However, in order to overcome the obstacles and address the constraints, capacity building-related support is also viewed as important, including agricultural training and lectures as well as support to help solve concrete problems in the field. Moreover, issues such as lack of time, not being informed or lack of permission from the husband, were viewed as challenges to attend capacity building trainings, workshops and meetings. Moreover, the majority of the survey participants mentioned that they never or hardly received any information or advice from extension service on agricultural production.

These insights, related to capacity building for the agriculture sector and in particular within the context of reducing disaster risks and adapting to climate change, even if from a limited number of female farmers are crucial in order to help to better inform design, planning, implementation as well as monitoring and evaluation of capacity building interventions. This may involve better dissemination of information and knowledge about agricultural good practices and technologies available for disaster risk reduction, including capacity building training to field test, validate and potentially replicate and update some of these options as well as a gender mainstreaming intervention to ensure the involvement of both women and men, thereby addressing gender inequality and promoting gender empowerment. The findings from this survey may also be valid in other parts of the country or in the neighbouring countries within the region; however, further research will need to be undertaken.

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Chapter 8
Commentary on China's Current Food Security Status, Future Trends, and Responses in the Face of Climate Variability

Victor R. Squires and Haiying Feng

Context and Setting

The leadership of China places a high priority on food security (Squires et al. 2015, Scott and Si 2019; Kuteleva 2016). Investments such as rural access (infrastructure like roads, railways) and agricultural research have allowed China to feed itself in the face of various predictions to the contrary. Now that food security has become a primary focus for many governments of food-marginal countries, multiple strategies will become essential, including food reserves. Food reserves around the world have been allowed to decline over recent decades. China has dealt with grain reserves in a managed way in China (Squires et al. 2015). At the same time, China has increased yields, production, and cultivated area by huge research investments and political might and investment. Today China is a leader in both farming new and foreign lands (Squires 2018) and in agricultural research, as well as being the world's largest food producer.

These multidimensional challenges are closely associated with various changes in China's agro-food system over the past few decades (Squires, Hua and Wang, 2015; Wang et al. 2017a). The changes in the agro-food system go far beyond the agriculture sector and rural spaces.

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China Food Policy

A 2015 special issue of the *Journal of Agrarian Change* on "Agrarian Change in China" discussed the dynamics, policy environment, and political economy of agricultural capitalization in recent years. The agrarian changes are characterized by rapid industrialization, capitalization, and commercialization of the agriculture sector (Zhang et al. 2015). The engagement of industrial and commercial capital from above and the proliferation of tenant farming from below explain the differentiation of rural classes. The grain self-sufficiency policy and the recent reform of the rural *hukou* (household registration) system are also found to have marginalized peasant farming and encouraged the rise of agrarian capitalism in China (Andreas and Zhan 2016). Similar trends are observed in the development of the so-called dragon-head enterprises (Chinese agribusinesses)[1] in the livestock industry (Schneider 2016; Li et al. 2018).

Food systems in China, as elsewhere, face challenges to become more resilient (Zhang 2018). On the one hand, although China is categorized as "moderately low" in terms of food insecurity in FAO's Hunger Map in 2015, and just 9.7% of its population (133.4 million) is undernourished (FAO 2017; Zhou 2013), hunger still prevails among its poor. On the other hand, obesity and diet-related health epidemics such as diabetes and hypertension are rising significantly. At least 32 billion USD worth of food is thrown away annually in China (Zhou 2013) which generates tremendous environmental, economic, and managerial costs (Liu et al. 2013). Problems within the agricultural system are also urgent as the depletion of soil and water resources has been jeopardizing both the quality and quantity of the country's food supply. Along with the widening income gap between cities and the countryside, Chinese farmers are struggling to make a decent living from farming their small plots (Su et al. 2015; Oxfam Hong Kong 2015). As a result, rural-urban migration has left millions of children, women, and elderly alone in rural communities, leading to a range of negative consequences (Ye et al. 2013, Jacka 2014).

Impact of Climate Change on Food Security

As home to the world's largest population and a generally self-sufficient food producer, any decline in Chinese agricultural production would have grave global consequences. The projections for China outlined by the IPCC point to an uncertain future if the agricultural benefits promised via technological innovations fail to offset some of the climate change impact stated by Piao et al. (2014).

The IPCC estimated China's yields of rice, wheat, and maize (corn) will drop about 20–36% over the next 20–80 years (IPCC 2017). While these estimates are based on future scenarios, declines in key cereal production in important areas of China have been observed. Climate change is reducing water availability and increases in evaporation and therefore increasing the demand for water needed for irrigation, which will limit crop productivity in affected areas to a significant extent. Relatively small reductions in rainfall will translate into much larger reductions in runoff. Marktanner et al. (2011) indicated that the nexus of climate change and food security is complex. A FAO report in 2008 identifies more than 100 links between climate change and food insecurity. Specifically, the FAO examines the climate change impacts of CO_2 fertilization, increase in global mean temperature, precipitation changes, and more extreme weather events on food system assets, food system activities, food security outcomes, and well-being (FAO 2008, p. 14–19).

With Regard to Availability of Food, Climate Change

- Adversely affects rural livelihood bases through a decline in water availability, soil erosion, desertification and salinization (particularly for coastal agricultural lands), droughts, floods, and wildfires
- Increases pest and disease problems (locusts, yellow rust, and the like)
- Likely reduces agricultural output
- Likely exacerbates the existing inequalities between rich and marginalized populations
- Affects livestock health and productivity
- Negatively affects fish supply

With Regard to Access to Food, Climate Change

- Could reduce access to food of people whose livelihoods depend on agriculture, livestock, forestry, and fisheries (especially smallholder, subsistence, rain-fed farmers, and pastoralists)
- Could lead to livelihood losses in urban populations (extreme weather conditions, coastal erosion, and flooding) and, as a result, could reduce food access of vulnerable urban populations
- Could reduce access to drinking water
- Leads to an upward trend of food prices and increases their volatility
- Creates poverty in rural communities
- Could spur internal and external conflict that disrupts access to markets

With Regard to Utilization of Food, Climate Change

- Undermines the availability and efficient utilization of food through factors like heat stress, disease, malnutrition, and the deterioration of sanitary conditions
- Increases competition for scarce public health services

- Increases likelihood of diseases due to epidemics from food and waterborne diseases such as cholera, malaria, dysentery, etc.

With Regard to Stability/Continuity of Food Supply, Climate Change

- Disrupts continuous availability through trade restrictions in response to climate change-induced catastrophes
- Leads to the collapse of social safety nets if the creation of fiscal space does not keep up with rising social assistance needs

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Farmers must adapt in order to mitigate the impacts of climate change. Whether farmers are willing to adopt new measures or improve their ability to adapt is crucial to mitigate the negative impacts of climate change. The Chinese government has paid considerable attention to the formulation and implementation of pro-adaptation policies. In 2013, China's National Development and Reform Commission issued a revised National Strategic Plan for adaptation to climate change that emphasized the importance of adaptation in the agricultural sector (NDRC 2013). Agricultural planting seasons and methods, farming systems, soils, and environmental and climatic conditions vary across China's 34 provincial administrative regions. Agricultural adaptation to climate change is a dynamic process with a large variation in the region, physical and socioeconomic contexts. Hence, the formulation of a uniform adaptation policy that guides farmers in the whole of China to adapt to climate change is difficult. Climate change and its impacts on water resources and crop production is a major force with which China and the rest of the world will have to cope in the twenty-first century.

China experienced explosive economic growth in recent decades, but with only 7% of the world's arable land available to feed 22% of the world's population, China's economy may be extremely vulnerable to climate change. Notwithstanding clear evidence of warming that has occurred in China in recent decades, current understanding does not allow a clear assessment of the impact of anthropogenic climate change on China's water resources and agriculture and therefore China's ability to feed its people. Agriculture is one of the most important economic sectors, contributing 11% to GDP in 2013. China is the world's largest agricultural economy with farming, forestry, animal husbandry, and fisheries accounting for approximately 11% of its GDP. There are 425 agricultural workers (200 million farming households) in China. A little over a decade ago, China was home to 700 million farmers. They made up about 60% of the population.

Arable lands (130 Mha) span temperate, subtropical, and tropical climates (Fig. 8.1). Single cropping is common in northern China, while multi-cropping rotations dominate south of 40^0 N. Rice, wheat, and maize are the main crops, together accounting for 54% of the total sown area and 89% of the grain yield in 2013.

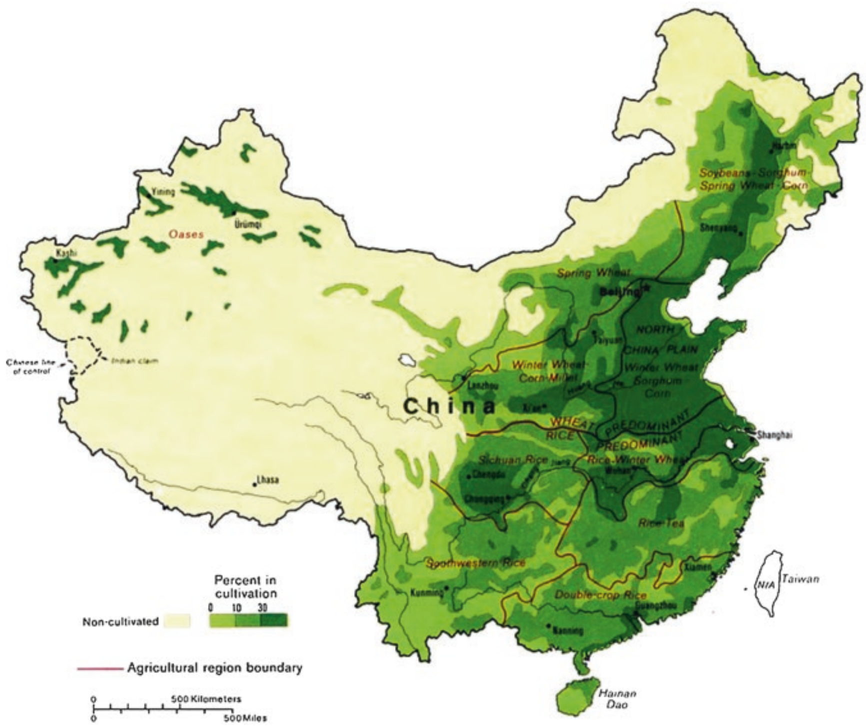


Fig. 8.1 Map of principal arable land/cropping areas in China

Climate Change and Its Potential Impacts on Water Resources and Agriculture in China Over the Past Five Decades

Recent research strongly suggests that temperature increases since 1980 and accompanying changes in precipitation have already had demonstrable but varying effects on agriculture. Regional warming has extended the length of the potential growing season for crops, allowing both earlier planting and later harvesting, and northward expansion of rice planting. For instance, the growing season of cotton in northwest China was lengthened by 9 days during 1983–2004. In parallel, the number of frost days shows a decline across most cropland regions. Data from the Chinese National Bureau of Statistics suggest that warming has already enabled a significant northward expansion of rice planting in Heilongjiang Province (the northernmost region of China) from 0.22 Mha in the early 1980s to 2.25 Mha in 2007, that is, a northward shift from 48 to 52^0 N. In parallel, rice yield in this province has increased from 0.7 to 14.2 Mt over the same period, owing mainly to improved practice. All these changes suggested that crop yield in the temperate climate zones of north China has benefited from the increased temperature. For most regions within China, climate change has been a drag on yields. Due to changes in precipitation and solar radiation in the past three decades, there has been a 1.2–10.2% reduction in wheat yields in southern China (Tao et al. 2014) (Fig. 8.2).

Average growing season temperatures in many agricultural counties in China are already above the optimum in the regions where many of China's most important crops now grow, including wheat, rice, corn, barley, sorghum, and soy (Fig. 8.3).

Over the last few decades, China has experienced a pronounced warming. Precipitation has increased in the south and northwest of the country; in contrast, the northeastern part has suffered from drought. These changes have already

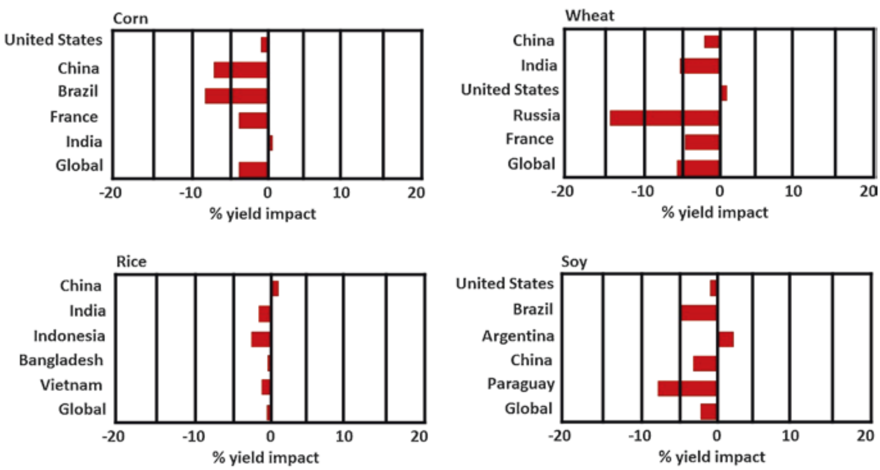


Fig. 8.2 The horizontal bars show how climate change has affected yield growth over the past three decades in the USA and a number of Asian countries, including China

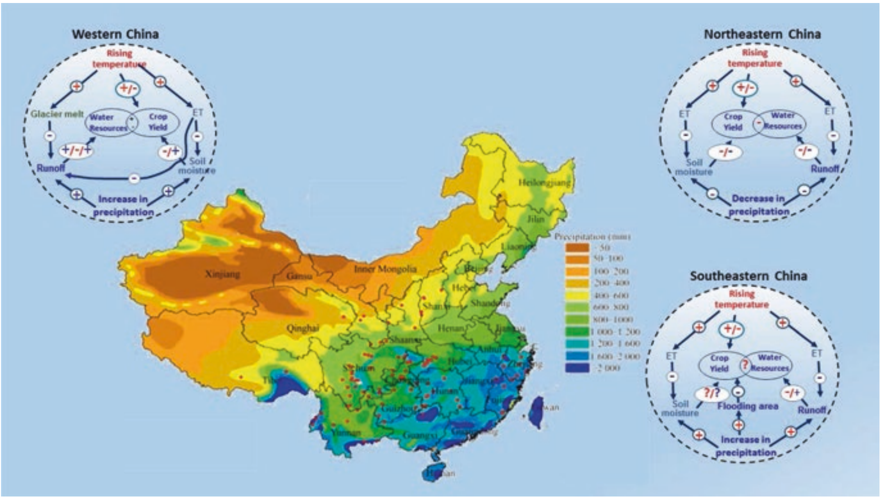


Fig. 8.3 Schematic diagram of climate change and its potential impacts on water resources and agriculture. Impact cycle diagrams for southeastern, western, and northeastern China are superimposed on the annual precipitation map of China

produced significant impacts on agriculture as well as water resources. In western China, reducing glacier mass driven by rising temperature and increased precipitation caused an increase in runoff that benefited agriculture in western China. In northeastern China, warmer conditions and decreased rainfall have been accompanied by increased drought, which produced a negative impact on agriculture. The wetter southeastern China has had more rainfall with an increase in high rainfall events.[1] These increased extreme rainfall events are likely to cause decreased crop yields, particularly through increased flooding. It is not clear whether the decrease in soil moisture and runoff due to the increase in evapotranspiration (ET), driven by rising temperature, is beneficial for crop yield in southeastern China, because this region has high precipitation and because some modeling suggests that there will be more winter rainfall. This increased precipitation would be counter to the cropping patterns.

Crop production has already begun to shift in response to higher temperatures. For example, rice production in China[2] is already shifting north. Data from the Chinese National Bureau of Statistics suggest that warming has already enabled a significant northward expansion of rice planting in Heilongjiang Province (the northernmost region of China) from 0.22 Mha in the early 1980s to 2.25 Mha in 2007, that is, a northward shift from 48^0 N to 52^0 N. All these changes suggested that crop yield in the temperate climate zones of north China has benefited from the

[1] Guangxi Autonomous Region has up to 30 times the expected rainfall recently and severe flooding has occurred.

[2] Robert Hijmans, "Relocating Rice Production in China," *Rice Today* 6, no. 4 (2007): 25

increased temperature. In parallel, rice yield in this province has increased from 0.7 to 14.2 Mt. over the same period, owing mainly to improved practice. Factors unrelated to climate change such as technical innovations, agricultural policies, and changing diets also contribute to these shifts, but climate is a major factor.

Most studies of the biological effects of climate change on crop production have focused on yield. A second impact, much less studied, is how the *quality* of food is affected by climate change. As crops and animals respond to changing weather, a change in the nutrient value of crops as well as a change in the mix of available foods is likely. Raising livestock in China, especially northern and NW China (Squires et al. 2009), is a traditional activity contributing to the livelihoods of millions of rural communities. Livestock make use of the scarce feed in the predominantly arid lands to convert them into nutritionally and economically valuable products. The productivity of the livestock sector is challenged by the scarcity of natural resources in terms of feed and water, lack of supporting infrastructure and services, and a history of arbitrary policies that affected the sector negatively. In addition, rangelands, the natural feed resource for mixed and pastoralist systems, have been largely degraded leading to loss of biodiversity, soil erosion, and a decrease in their carrying capacity, thus livestock productivity (Squires et al. 2009).

The Relationship Between the Development and Food Security

This aspect has become more and more decisive since the beginning of the twenty-first century. This has led to the emergence of a new food geopolitics in the world. The classical security paradigm has shifted to water, food, energy, and environmental security areas since the beginning of the twenty-first century. With the impact of climate change, this process will continue and the effects of new food geopolitics will increase (Fig. 8.4).

The concept of food security also includes food safety. China is struggling with how to comply with the recognized pillars for the food safety (sanitary suppliers, sanitary preparation, sanitary transportation, and sanitary serving.) Food safety is an integral part of food security; yet, because of the long-standing focus on maintaining basic food availability, until very recently food safety was not high on the list of priorities for the Chinese government (Jen 2018). Ever since the melamine event,[3] China has faced challenges of food safety both domestically and globally. With the economic development, the Chinese consumers are demanding high-quality, nutritious, and safe foods from the food industry but are not willing to pay higher prices. The Chinese food chain system of mostly small and medium enterprises presents challenges to the government to monitor and implement food safety laws and regulations. The academia and media are learning to take on their responsibilities with some success.

[3] Melamine was found in dairy products, including infant formula

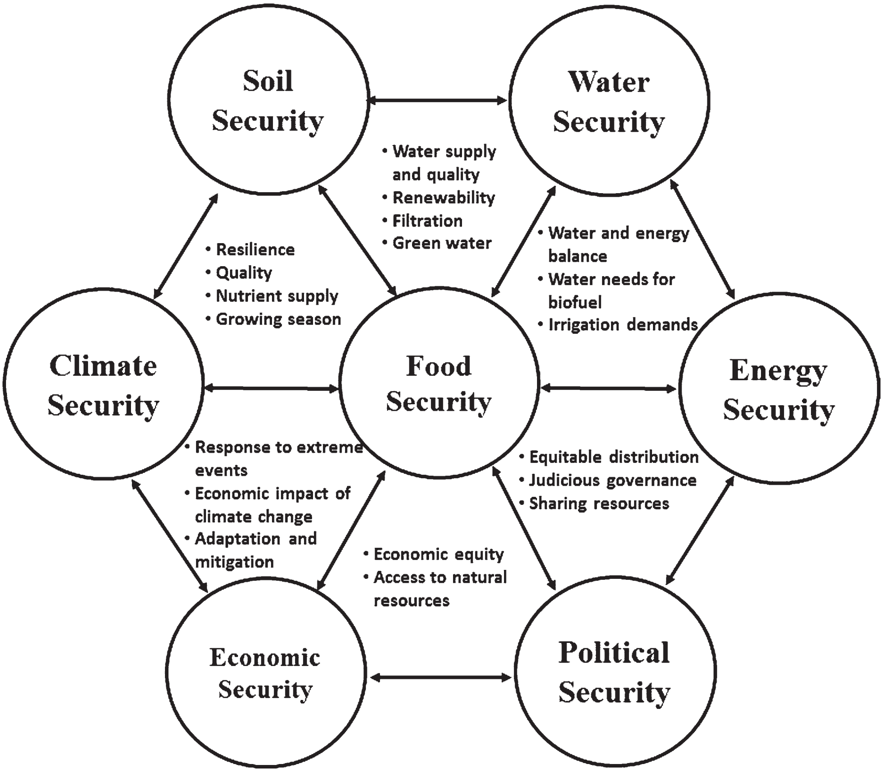
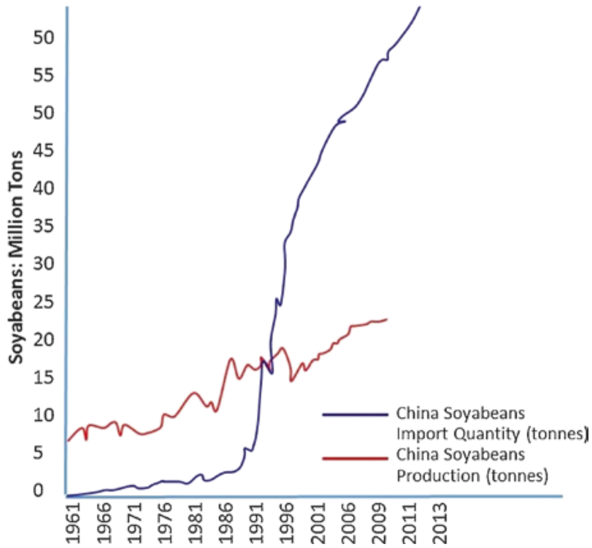


Fig. 8.4 Food security is dependent on a number of other important systems that include economics energy, climate, and water security

China's aspiration for self-sufficiency is in conflict with food safety in two major aspects. First, China's government is motivating farmers to maximize production, which has led to the development of some unsustainable and harmful agricultural practices (e.g., overly intensive farming, excessive use of fertilizers and pesticides). Second, China's government is determined to make basic foodstuffs as affordable as possible for the populace and adjusts the prices of agricultural goods. As a result, producers are under pressure to cut costs in the drive for profitability by using illegal additives and adopting unsafe food processing practices. The Chinese middle class, which constitutes about 24% of China's population (300 million people), has particularly high expectations about food quality and safety. Because of the huge scale of China's food industry and its decentralized and fragmented structure, progress on food safety control and regulation has been limited (Squires et al. 2015; Kuteleva 2016). And we have seen in recent history that food dependence can bring significant risks to the safety of imported food. We should also see that the various facets of food security and food safety are now placed in a more central position in the

Fig. 8.5 A seemingly unending demand by China for more soybean may have serious repercussions in Latin America and other supplier countries



overall security concept and that their relationship with national security increases rapidly.

As a result, wise states need to be aware of changing their security paradigm and take steps now to develop new food security strategies. Moreover, the challenges faced by China's food system have recently become even more complex, with the escalating trade war between China and the United States and the potential restructuring of the global food trade order (Perraton 2018). The tension of a trade war is not only reshaping global market for food commodities but may also perpetuate further environmental destruction in South America, where China's demands for soy have been increasing; Fig. 8.5 shows the widening gap between China's demand for soybean and the local production.

Such tension may also result in higher prices for pork and other foods[4] in China's domestic market, affecting daily food consumption throughout the country. Through this process, the changing politics in the international arena are intertwined with domestic food production and consumption. There are complex transitions and nexus between land, food production, and consumption. They help to explain the complexity and diversity of China's rapidly changing food sector and its divergent socioeconomic context. These are key elements of a food systems approach, which can be defined as "a holistic approach to describing and analysing food systems [that] allows the direct linking of ecosystem services to a critical part of human well-being [i.e., food security]" (Ericksen et al. 2010, 40, see also Ericksen 2008). Si and Scott (2019) analyze the multidimensional and multifaceted situation in a special issue of *Canadian Journal of Development Studies (2019).*[5] There are calls

[4] Most soy imports are for feeding livestock like pigs and poultry.

[5] Volume 40, issue 1,

for a more holistic perspective in both research and policy making to understand the challenges facing the global food system and also explore potential solutions. The impacts of the top-down and bottom-up initiatives are unfolding across various segments of the food system. They are collectively shaping the innovations beyond food production and reconfiguring the food system as a whole.

A food systems approach (Erikson, 2008) includes consideration of the entire food supply chain, from food production (and production inputs) to processing, distribution, consumption, and waste disposal. Thus, it is more than merely a food production focus (Si and Scott 2016; Ericksen 2008; Foran et al. 2014). Seemingly trivial and unrelated matters, for example, seeds of registered varieties like canola or GM maize, virtual water embedded in food trade, tea production and markets, and support to develop organic agriculture all need to be considered. These aspects were well canvassed in the special issue of *Canadian Journal of Development Studies* (op.cit). Further along the supply chain, there is need to have analyses of food supply in cities, food provisioning channels between farmers and their social networks, and the role of CSA in food consumption and in addressing food safety concerns. A food systems approach likewise includes attention to biophysical as well as socioeconomic and cultural aspects.

Air pollution negatively impacts food security. Sun et al. (2017) review the current literature on the relationship between air pollution and food security from the perspective of food system. They emphasize that agricultural emissions, which substantially contribute to air pollution, could happen at every stage along the food supply chain.

Despite the rapid evolution of China's food system and the urgency of coping with these critical challenges, state-led developmental approaches (advancing an agri-industrial development model) to revitalize the countryside and boost sustainable rural development have failed to address these social and cultural concerns effectively (Si and Scott 2016) (Fig. 8.6).

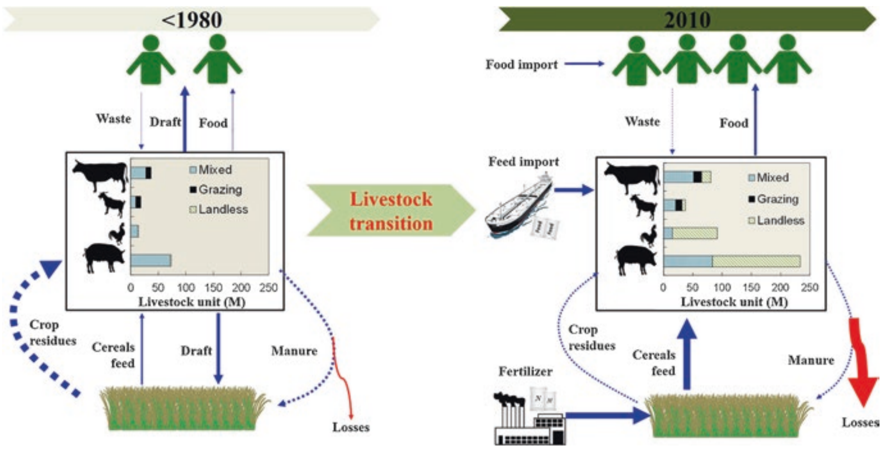


Fig. 8.6 There has been a marked shift in the way in which livestock were raised and utilized. (Source: Bai et al. 2018)

Since the mid-2000s, rural development and politics in China has entered a new phase that revolves around what the central government calls "agricultural modernization." Transforming the once-dominant smallholding, family-based agriculture has become a focal point of the government's program of rural rejuvenation, where a range of economic changes unleashed by urbanization and industrialization also converge. This opens up spaces for various non-state actors to gain influence over food production and consumption, such as the significant roles of civil society organizations, alternative food initiatives, farmers, and consumers in promoting sustainable food production and ethical consumption (Scott et al. 2014; Schumilas and Scott 2019). The coexistence of top-down and bottom-up forces in China's food system transformations demands more integrated analyses of key changes underway in its agro-food sector, including, but are not limited to, the following themes:

1. The policy and practice around the protection of China's agricultural land and national food security
2. The marginalization of small-scale farmers (and their knowledge) through the vertical integration and modernization of agricultural production
3. Diverse responses to heightened food safety anxiety and an increasingly disembedded food system
4. Emerging "alternative food systems" and "alternative food networks" in China, such as organic food and agriculture, ecological farmers' markets, community-supported agriculture (CSA) farms, and grassroots organizations promoting environmental and social values for a more sustainable food system

The super marketization of food retail, dietary changes, and rampant food safety crises, to mention just a few of the trends, have attracted much scholarly attention (Garnett and Wilkes 2014; Scott et al. 2018). Traditional food outlets face increasing competition from new food retailing formats. The overconsumption of vegetable oil and meat (Hansen and Gale 2014, Liu et al. 2008) and the decreasing consumption of coarse grains are associated with the growth of diet-related noncommunicable diseases (Zhang et al. 2015; Chang et al. 2018). On a more positive note, perceived food safety risks are fueling a rebuilding of relationships between people, food, and place through the pursuit of new food sources and food practices (Si 2017, Wang et al. 2017b). The role of China's political economy must be mentioned. It is manifested in a developed[6] rural land rental market, agrarian transformation toward agro-industrialization and vertical integration, the growth of China's domestic organic market, and an emerging civil society – in shaping opportunities and constraints for developing a more sustainable, resilient food system.

[6] Not everywhere, but certainly in the major food producing areas

The Winds of Change

In the past few decades, dramatic changes in China's food system have generated economic, social, and environmental consequences that jeopardize its sustainability. Both the Chinese state and civil society have responded to these challenges, with diverse initiatives. The state has promulgated a particularly strong focus on developing "green" policies. Green production and sustainable farming practices, under the overall framework of supply-side reform, was one of the highlights of State Council's policy document. "Green" actually becomes one of the most frequently used words in the document. Supply-side reform in China's agricultural sector is to increase the output of high-quality products based on green and innovative production. It is part of the broader push toward ecological civilization and should in unison with the policy on rural rejuvenation. In its simplest form, ecological civilization is a dynamic equilibrium state where humans and nature interact and function harmoniously. The concept of an "ecological culture" is believed to have been put forth by a biologist in the former Soviet Union in the 1980s (Gare 2012), but the concept did not see widespread practical use until the mid-2000s when the term "ecological civilization" was translated and adopted by the Communist Party of China as an explicit goal. Since then, China has embraced the concept with vigor, notably as a central policy objective mentioned at several national congresses of the Chinese Communist Party and written into China's "13th Five-year Plan" (2016–2020), which promotes the development of ecological civilization. Achieving ecological civilization is an extremely broad goal and involves addressing a range of human–environment issues including, but not limited to, air, water, and soil pollution; remediation of contaminated areas; clean energy; climate change mitigation; food security; ecosystem health; sustainable land use; human welfare; and social justice and equity.

China is often cited as an exceptional example of a developing country that has succeeded in increasing food productivity and availability, improving access to food, and ensuring stability of food supplies. While China's record in protecting its basic food security is indeed impressive, the challenges facing its pursuit of food security are still many and complex (Kuteleva 2016). According to Garnett and Wilkes (2014), as cited in Kuteleva (2016), China's government still concentrates considerable resources on eliminating hunger among the 150 million people who live in rural areas (Fig. 8.7).

However, recent social and economic developments, such as marketization of the economy, rapid urbanization, and rising incomes, *add complexity and pressure* [italics ours] to the Chinese food security situation Long et al. 2015. China is experiencing rapid growth in food consumption and fundamental transformations in the food system, and its pursuit of food security now includes meeting the dietary aspirations of an increasingly affluent population that seeks to consume more meat, poultry, fish, fruit, and dairy products (Liu et al. 2008).

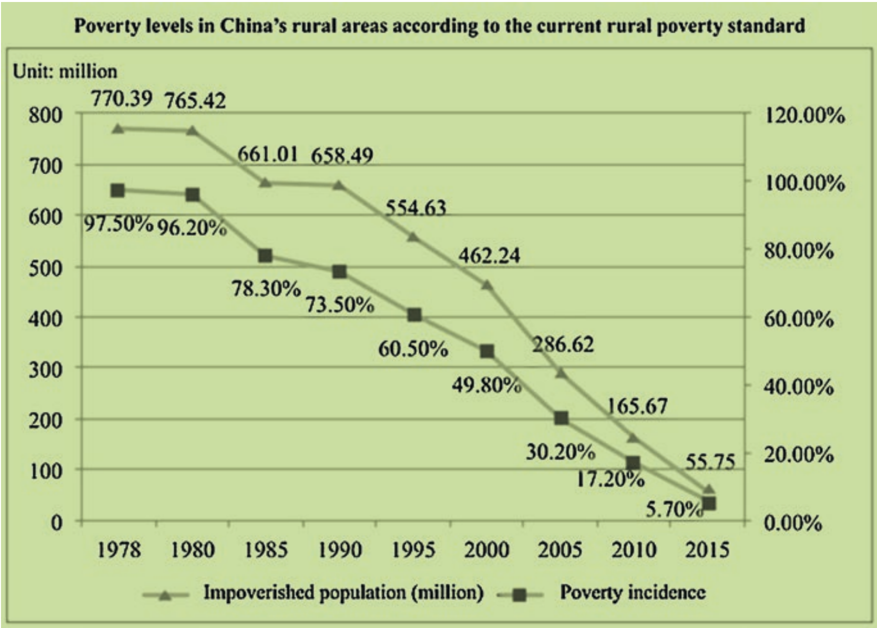


Fig. 8.7 Poverty alleviation is a major goal and success has been (and continues to be) made

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Part III
Food Security and Livelihoods

From South Africa comes a story (*Donkor et al.)* about the Ndunakazi project (named for the province of Kwazulu-Natal in South Africa, where the project was implemented). It is part of broader program that intends to ensure that no one is left behind. *Inter alia* it sought to improve the vitamin A status of children through the cultivation and consumption of vegetables and fruits rich in provitamin A. The consumption of the vegetables introduced by the project has greatly improved the vitamin A status of the Ndunakazi people. About 85% of their intake of vitamin A comes from the new crops. A further positive impact has been the contribution of the vegetables to the intake of calcium and iron and, to a lesser extent, of magnesium, vitamin C, and riboflavin.

Environmental governance is an essential part of any transformational adaptation. The study from Indonesia (*Jupesta et al.)* aimed at reducing/eliminating fires in the forests and woodlands, reducing smoke hazard, and exploring more ecologically sound ways to grow food. The interplay between private interests (mostly palm oil producers, the environmental protection agency, the local villagers) is explained.

Urban areas have potential to be used as a food production base as the study from Nigeria (*Aliyu Barau*) demonstrates. It examines the feasibility of zero-acreage farming (Zfarming) in moderately large city. Similarly, the adoption of organic farming techniques can successfully regenerate soils that are low in soil carbon and other essential components of fertile soil. The experience from Bangladesh is explained (*Md. Shafiqul Islam*) and the benefits, in terms of sustainable production and better nutrition of those who follow these management practices, are summarized. Special reference is made to more efficient use of water under organic farming systems.

Chapter 9
Attitudinal Changes Towards Agriculture Through the Generational Lens and Impact on Engagement in Related Activities: Case Study From a Mountainous Area

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Introduction

Mountains in Africa collectively occupy approximately 3,000,000 km2 of its surface area (Bagoora 2012; UNEP 2012). These mountainous areas aside from their aesthetic value also provide critical livelihood-sustaining services such as supply of water, food and energy as well as other essential needs of people across the social strata especially vulnerable groups (UNEP 2012). In addition, mountains supply more than half of the African populace with water as most of Africa's principal rivers have their source from mountains that sustain the fundamental needs of both up- and downstream communities (Alweny et al. 2014).

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Moreover, by virtue of their high fertility, mountain areas sustain highly intense agricultural practices ranging from commercial to subsistence smallholder systems (Mugagga et al. 2010). Furthermore, the slopes of mountains support a variety of ecosystems mirroring the differences in climate, soils and landscapes (Alweny et al. 2014). For example, the fynbos biome in South Africa hosts circa 6200 flora species regarded as endemic which is not an isolated case. The associated biodiversity cum ecosystem services sustain the production of both timber and non-timber forest resources, including nutrition and essential medicines, whilst the spectacular massifs afford alluring panoramas with viable potential for tourism (Alweny et al. 2014).

There exists a plethora of land-based livelihood activities in mountain environments, which together support the livelihoods of large sections of the South African populace especially in the rural areas (Hoffman 2015). However, the manner in which the environment is utilized and valued has essentially changed over the last century (Hoffman 2015). Land was a chief resource in the pre-industrial era, when the economy and social relations were founded on agriculture (Cousins and Walker 2015). However, the number of people directly engaged on agriculture has significantly dwindled with the onset of the mining revolution towards the end of the nineteenth century which is akin to the quota of agriculture to the country's gross domestic product (Cousins and Walker 2015). In 1980, 57% of the population was categorized as rural, but this was reversed by 2001 as 57 % of the population was reported as urban rising to 63 % in 2014 (Cousins and Walker 2015). Furthermore, the chief sources of livelihoods have shifted from being disproportionately land-based to depend on wages, remittances and (increasingly) on social welfare grants. Consequently, in contemporary times, agriculture forms the chief livelihood of a tiny minority even so, small-scale farming in the former homelands is vital for household food security (Cousins and Walker 2015). For example, whilst there were 120,000 South African farmers in 1994, this had dwindled to 37,000 by 2012 (Farmers Weekly 2012). This has led some to posit that there is a shift towards 'deagrarianization' of rural areas (Neves and Du Toit 2013) which affects the rural economy and the rural youth who perceive little potential in the sector (FAO 2016). Despite this assertion, agriculture still has a vital role to play in sustainable development in Southern Africa and globally. Thus it could be surmised that the future of food security would depend on these rural youth. However, across the globe, youth hardly ever identify themselves with agriculture or rural areas (FAO 2016). Rural youth in particular are confronted with several challenges in their attempt to make a livelihood (FAO 2016). Increasing pressure on arable land the world over is an impediment for starting a farm.

Agriculture and Youth Employment in South Africa

South Africa's relatively good infrastructure, counter-seasonality to Europe, abundant biodiversity and aquatic resources, as well as competitive farm input prices can propel it into a global leader in the agricultural sector (European Parliament 2015).

Agriculture's potential to create jobs for the nation's teeming youth is one reason for its prominence in South Africa's National Development Plan (NDP) which seeks to provide a million jobs by 2030. Hence there are developing state interventions to enhance the country's agricultural training institutions so as to draw more youth into the sector (Farmers weekly 2012). The goals of NDP pertaining to agriculture require a skilled human resource base. It also demands delivering comprehensive support for smallholder farmers such as accelerating land reform and provision of technical, infrastructural and financial support (DAFF 2016). This has become urgent as South Africa is third in the world for countries with high levels of employed young people within the age cohort of 15–24, as over 50% of South Africans in this age bracket are projected to be unemployed (South Africa info 2014).

Furthermore, with climate change and variability becoming more palpable, it has become imperative to adopt best management practices and to improve agricultural resilience (Bezu and Holden 2014; FAO 2014). This involves having the requisite skilled human capital to make such resilient agriculture successful. The youth represent a potential human resource base which can be nurtured with the necessary skills to realize such resilient agriculture. However in spite of the potential of agriculture to help create income-generating opportunities for the world's teeming rural youth, problems associated predominantly with youth participation in the sector bedevil its development and progress in the rural milieu (FAO 2014). Placing a premium on rural development and agricultural investment – crops, livestock, forestry, fisheries and aquaculture – is crucial to ending poverty and hunger.

This study reported here thus contributes knowledge on enhancing youth involvement along the agricultural value chain. The core objective is to interrogate the causal factors that impede or disincentivize the youth from engaging in agriculture and proffer some possible remedies to addressing these challenges. Given that a key narrative in the Sustainable Development Goals (SDGs) is *Not Leaving Anyone Behind*; addressing the needs of vulnerable groups such as the youth is necessary to realizing such noble objectives. The effective intergenerational cross-pollination of ideas is crucial to the successful management of ecosystem services that sustain agriculture and the associated rural smallholder systems (Fig. 9.1).

United Nations member states have acknowledged that the dignity of persons is essential and that the SDGs should be realized for all people and segments of society. Moreover, they have committed to redouble efforts at meeting the basic needs of those furthest behind (UNSTATS 2018). Mountain communities by virtue of their remoteness and rugged landscapes are often marginalized – benefiting very little from development dividends. Moreover, the youth and elderly represent vulnerable groups which are disproportionately affected by such skewedness. In addition, the environmentally sensitive livelihoods of these rural mountain dwellers and related fragile ecosystems make them vulnerable to climate change and compromised ecosystem service functions (Mutoko et al. 2015). Agriculture represents a key lever for sustaining these vulnerable communities and their livelihoods (Hoffman 2015). The elderly generation embody the indigenous knowledge or biocultural heritage which has been bequeathed from past generations. By virtue of the fact that indigenous peoples have adjusted to severe climatic conditions across several generations, this

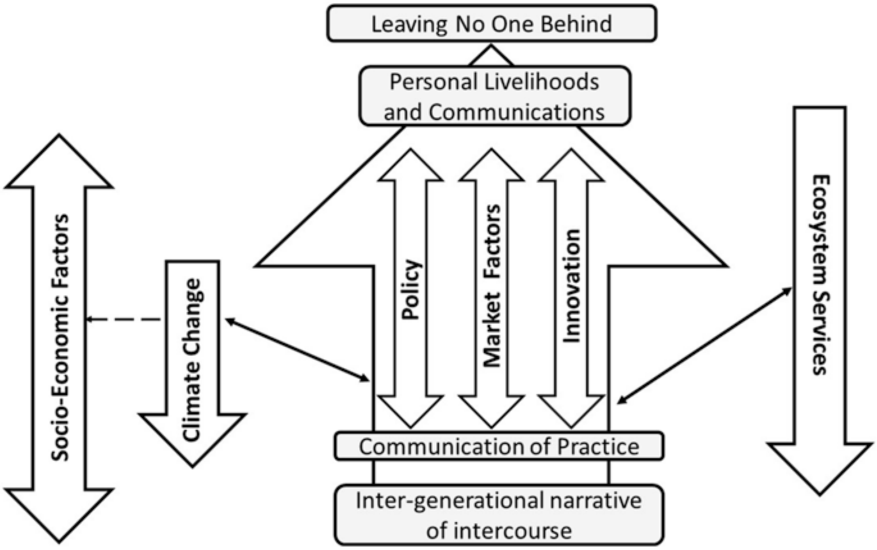

Fig. 9.1 Flow diagram of thematic areas of the study

heritage is vital for food security in the light of climate change (IIED 2018). This is transferred to the youth by way of socialization. The youth are also exposed to new knowledge which calls for an intergenerational intercourse to build communities of practice that will propel the entire agricultural value chain (Mutoko et al. 2015). This is complemented by an enabling policy framework, favourable market conditions and the innovation or adaptive capacity of the farmer (Tibesigwa et al. 2016). Ultimately, this process feeds into building resilient agricultural systems and livelihoods that help to Leave No One Behind (Fig. 9.1).

Methodology

Narrative inquiry or narrative analysis is a qualitative research technique which employs field texts, like conversations, interviews and life experience amongst others, as the units of analysis to study and comprehend how people make meaning in their lives as narratives (Clandinin and Connelly 2000). From the point of educational research, some argue that human beings are essentially storytellers who, as individuals and communities, lead storied lives. Hence an analysis of the narrative is the key to understanding the ways people experience the world (Connelly and Clandinin 1990). Ultimately education and educational research are the production and reproduction of individual and social stories; students, teachers and researchers are regarded as story reciters and characters in their personal and other's stories (Connelly and Clandinin 1990). In this study, analysis is hinged on the conversations and interviews on the changing attitudes towards agriculture between the youth and the older generation with the aim of understanding causative factors and the dynamics of this phenomenon.

Research Design and Data Collection

Data collection was done in October 2015 and March 2016 employing household interviews and key informant interviews. The data comprised of biographical information, views on attitudes and changing nature of rural agriculture. Socio-economic data were collected by medium of a semi-structured questionnaire in households. For the interviews, 50 community members were randomly sampled from the 4 constituent zones of the study site (Fig. 9.2). In addition, interviews were conducted with 20 key informants who were selected due to their unique insights on the thematic area under study (USAID 1996). The informed consent of each interviewee was sought

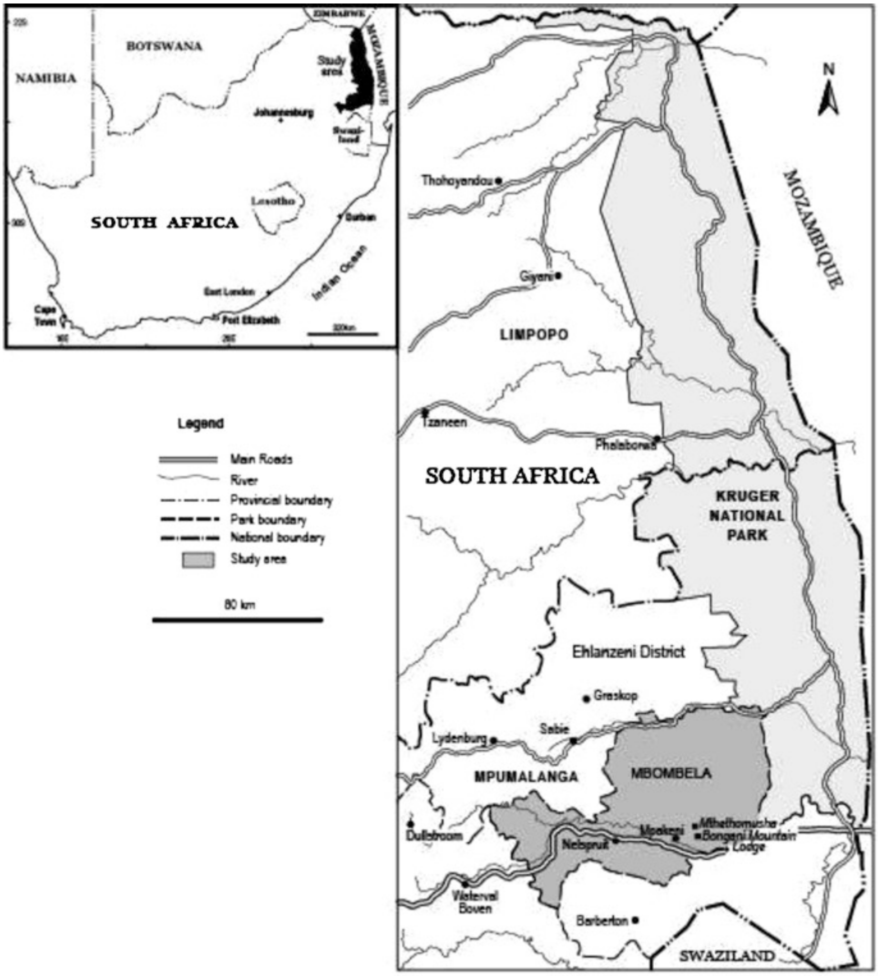

Fig. 9.2 Location of the study area
Overview of the study site (Mpakeni)

before the interview was conducted. As the study involved issues on ethics, ethics clearance was gained from the University of the Witwatersrand non-medical human subjects research committee with a certificate number H15/09/05.

Data Interpretation and Analysis

During the key informant interviewing process, pertinent points were noted and the interviews recorded and transcribed. Through a thematic content analysis, the principal recurring themes relating to the nature of attitudes and importance given to agriculture by the youth and the elderly were integrated as per *meaning condensation*. Consequently, the accounts of interview subjects were condensed into phrases mirroring the principal idea expressed (Kvale and Brinkmann 2009). All interviews were coded to guarantee the anonymity of respondents. The data interpretation and analysis is summarized in Fig. 9.3.

Study Site: Mpakeni Village

Mpakeni village is one of the four constituent communities which form the Mpakeni Tribal Authority together with Daantjie (where the chief resides), Luphusi, Zwelisha and Mpakeni. It is located in the Nsikazi District of the Mpumalanga Province

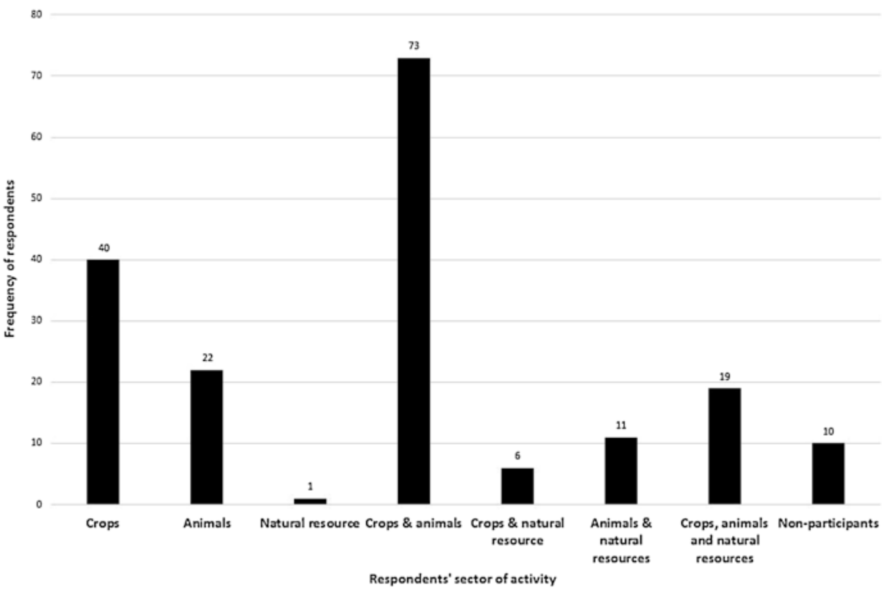

Fig. 9.3 Breakdown of livelihood options of sample population
Distribution of respondents across different sectors of land-based livelihood activities

(north-eastern South Africa), in close proximity to Swaziland and Mozambique. It is represented by the geographical coordinates 25° 29' 08" South, 31° 16' 38" East with an altitude of 821 m above sea level. Most people in the area of siSwati (Swazi) – and Xitsonga (Tsonga) (–) descent (Van Riet et al. 1997).

A homestead refers to the living space of a household and may comprise of a single or several houses (Ellis 2000). Furthermore a household is composed of single or several individuals who share a dwelling as well as meals (Haviland 2003). The household also represents the rudimentary unit of analysis in several socio-economic models (O'Sullivan and Sheffrin 2003). Nonetheless, there was lack of official census data on the population of the study site at the time of study (E., personal communication, July 5, 2015; N., personal communication, October 5, 2015). In order to gain an accurate projection of the Mpakeni population, relevant government agencies were consulted (L., personal communication, July 30, 2015). Other people who have done studies on related topics in the Mpumalanga province were also consulted and juxtaposed with published material on the area (Twine et al. 2003) to suggest an average of six individuals for a household. This household mean was also confirmed in the course of a community mapping process. In addition, Google Earth was employed in counting homesteads in Mpakeni. This involved performing a search on Google Earth with the target site being Mpakeni in Mpumalanga Province of South Africa at diverse scales (1 km, 500 m) to make the homesteads visible for computing. A hard copy was also made and compared with the digital version. Circa 270 homesteads were counted. An average of six people per household was multiplied by the overall number of homesteads computed from Google Earth to arrive at a population of 1620 individuals ($270 * 6$). The spatial outlook of the study site is depicted in Fig. 9.2.

Results and Discussions

To the best of our knowledge, this is the first study that looks at the intercourse of intergenerational dialogue premised in our mountainous context and its relation with sustainable agriculture and goal of Leaving No One Behind. It is pertinent to engage with the relations between individual stories and popular discourses or dominant narratives and evaluate the implications for requisite interventions.

Moreover, respondents provided diverse perspectives on the themes under investigation which were expounded in the aforementioned narratives. Consequently, the views of key informants concerning the dwindling interest of the youth in participating in agriculture compared to the older generation are woven around the tapestry of divergent narratives.

The majority of household heads were females with households receiving an average of three social welfare grants. There were a total of 183 respondents made of 81 (44.3%) males and 102 (55.7%) females (Table 9.1). The households had an average of six (6) household members, one person permanently employed and receiving an average of three social welfare grants.

Table 9.1 Breakdown of the sample population according to age and gender
Sociodemographic profile of study respondents (n = 183)

	Frequency	Percentage
Age range		
[a]18–24	7	3.8
25–34	27	15.3
35–44	50	27.3
45–54	30	16.4
55–64	25	13.1
65–74	31	16.9
75–84	9	4.9
85+	4	2.2
Total	183	100
Gender		
Male	81	44.3
Female	102	55.7
Total	183	100

[a]*NB. The age range starts from 18 in consonance with ethics requirement*

Table 9.2 Breakdown of agriculture-related activities of the respondents
Age distribution of respondents vis-à-vis their agriculture-related activities (n = 183)

	Frequency	Percentage
Age range		
[a]18–24	7	4.1
25–34	22	12.7
35–44	49	28.3
45–54	28	16.2
55–64	25	14.5
65–74	29	16.8
75–84	9	5.2
85+	4	2.3
Total	173	100

[a]*NB. The age range starts from 18 in consonance with ethics requirement*
The most predominant age groups in agriculture were 35–44 years, 65–74 years and 45–54 years in descending order

Agriculture is a key source of livelihood sustenance in many rural areas such as the study site (Fig. 9.2). Given the narrative of the importance of agriculture in the rural sphere, the agriculture-related activities of the respondents were appraised (Fig. 9.3). Furthermore the participation in agriculture in light of age cohorts was also considered (Table 9.2). Thus Table 9.2 highlights the age distribution as per the agricultural related activities of the study participants. In all 173 (94%) of respondents were involved in agriculture, whilst 10 (6%) were not involved in any form of agriculture (Table 9.2 and Fig. 9.3).

Study results also indicate that most respondents were involved in some form of agriculture-related activity (Table 9.2 and Fig. 9.3).

Thus 21.9% (40) and 12.0% of respondents were engaged exclusively in crop production and animal production, respectively, whilst 39.9% (73) were involved in crop and animal production, with the remainder engaged in a combination of different agricultural activities (Fig. 9.3).

Intergenerational Narratives on Agricultural Livelihood and Charting a Path for the Future

The intergenerational narrative thread shows that the elderly generation largely regard tilling the land and life in the rural context in a more positive light than the youth (Cousins and Walker 2015). This is encapsulated by respondent I, who serves as chairperson of the local farmers association, in response to a question on the claim that the youth are not as interested in agriculture as the older folk:

> To be honest with you. The youth don't like agriculture. They are lazy; all they just want is the finished product.

Conversely, the youthful narrative paints a picture of resistance to rural life and to the possibilities of agricultural work (Farmers Weekly 2015). This is vividly expressed in the words of respondent K, a former agricultural engineering (bio-resources) student from one of the nation's reputable universities. This was a rebuttal in reaction to a question on the claim that there is a marked attitudinal change towards agriculture amongst the youth:

> Old people have always been interested in agriculture but young people are disinterested. Blame the media; they advertise to the youth that they can do more with their lives than being stuck in a rural area doing agriculture.

Such youthful narratives contrast with the popular discourse in relation to questions of food security and sustainability. However, it is also understandable given historical conditions, the perpetuation of racialized unequal access to arable land that would make agriculture viable (Cousins and Walker 2015) and contemporary popular discourses that emphasize that freedom and achievement lie in escaping to cities and urban life (FAO 2014) as surmised from the narrative of respondent K.

It is thus evident that whilst the elderly narrative on agriculture and rural life borders on reverence, youth value it less highly. This shift in concentration from agriculture to alternative sources of income has led to the phenomenon of *deagrariarization* (–) characterized by increased feature of wages, remittances and social welfare grants on the rural landscape (Neves and Du Toit 2013). Education and modernization are often cited as causes for this change as well as eroding the influence of traditional institutions and culture (Cousins and Walker 2015). Hence, although improved educational levels in the rural areas have become evident (Rosenberg et al. 2015), it may have increased career options for the youth but not necessarily in agriculture. This is in contrast to the argument of 46% of respondents (B, F, H, K) that introducing agriculture to learners will bolster the adoption of agricultural livelihoods amongst the youth (FAO 2014). For example, respondent B (a youth leader) in response to a question on the youth's perception and involvement in agriculture surmised:

> Yeah they (the youth) feel farming is for the old and vulnerable but farming is a way of life. We (the youth) don't see the importance of farming when we have the money to buy what we can farm.

Similarly, respondent F (a former apartheid government employee in the Kangwane government) commented:

> Because the government we have now is different from the past. In the apartheid era, we were taught at a young age to farm. But now the young are smoking 'nyaope' (an addictive drug) which was not previously the case.

This is further buttressed by the account of respondent H, a local supervisor of the Expanded Public Works Programme (EPWP) which supplies poverty and income relief by offering temporary work for the unemployed to undertake socially useful activities:

> It is laziness. Young people are lazy. In EPWP (Expanded Public Works Programme) we are 30 people but those who are serious about agriculture are very few.

It is noteworthy that these comments were in response to a question on the claim that there is a marked attitudinal change towards agriculture amongst the youth.

Furthermore education and modernization facilitated by the post-apartheid era may have filtered those who genuinely are interested in farming from those who may have been coerced into it, as argued by respondent K. Under apartheid regulations, many were forced to remain rural dwellers (Neves and Du Toit 2013). This argument also smacks of political ecology and betrays the socio-economic changes which may be affecting the interest of the youth in agriculture.

The youth by nature are less risk averse compared to the elderly generation. This may account for their penchant to explore other sources of livelihood unlike their elderly folks who would prefer the stability of their farming activities. Nevertheless it has been observed that the youth are often on the fringes of the job market, without the requisite work experience and networks to secure employment (Rankin et al. 2016). This is buttressed by the accounts of respondents C and G. Thus during a focus group discussion with four unemployed youths, respondent C explained:

> Because it (desisting from farming) is a modern lifestyle (attitude). All the things being planted you can buy in the shops so there is no need to farm again.

However respondent G (a local farmer) gives another perspective to the debate in opining that:

> Some young people want to farm but they don't have money.

These were responses to a question on the claim that the youth are less enthused about agriculture in comparison to the older folk.

Moreover, even when employed, their status is often precarious as they are limited to temporary contracts. In addition, they are found in the job categories most sensitive to economic fluctuations and hence face higher likelihoods of retrenchment (Rankin et al. 2016). Nevertheless, in the face of rising youth unemployment, entrepreneurship such as in agribusiness provides an avenue to help the youth harness their potentials and contribute to rural development even as they escape poverty (Rankin et al. 2016). This may explain why some respondents label the youth as *lazy* (E, I) as they refuse to embrace available agricultural opportunities in the hope of finding non-existent jobs as portrayed in the narrative of respondent H. This point is clear from the account of respondent E (a local farmer) who in stating his opinion on the claim that the youth are not as interested in agriculture as the older folk argues that:

> The change in attitudes is because young people now eat food from restaurants. In my time we had to go to the farm to get farm produce to prepare food. We teach young people to farm but they are stubborn. They eat what we plant but refuse to go to the farm.

Respondents G and A, however, point to other background issues, such as climatic and financial challenges disincentivizing young people from agriculture activities. For example, respondent A (an agricultural extension officer) in a rebuttal as to whether growing of crops has reduced in rural areas:

> Yes people have stopped growing vegetables due to shortage of rain.

This suggests the elderly generation may have enjoyed more favourable climatic conditions and extension support (F, A) to incentivize their agricultural engagement compared to present times (Neves and Du Toit 2013). The issue of how favourable climatic conditions relates is confounded with the availability of arable land.

However the debate over land reform is a heated one which the Department of Rural Development and Land Reform (DRDLR) of South Africa, despite its far-reaching proposals, has largely failed to effectively address (Cousins and Walker 2015). When it comes to land, young people are less likely to buy land due to the high levels of youth unemployment, poor income of majority rural youth and escalating land prices (FAO 2011). Furthermore, loans allocated for land purchase are not easily accessed by the rural youth who are in dire need of such resources. In addition, in many cultures, the youth normally have to wait until adulthood to have their own piece of land as it is also often considered an abomination for young people to appropriate family land when their parents are not yet deceased (UN-HABITAT 2011). Whilst awaiting their patrimony, several young people are confined to subsidiary land rights and perform labour on kinship land which is often poorly remunerated. This could serve as further disincentive for their engagement in agriculture.

Respondent E surmises that agricultural and farming skills are often transferred from parents to their children. Such informal mentoring may have proved effective in ushering young people into rural agriculture in times past, but the youth deem this unwarranted as they can find whatever is planted on the farm in the shops as indicated by respondents B, C and D.

Respondent D (a traditional healer) exemplifies this in her account on the claim that the youth are not as interested in agriculture as the older folk:

> The young ones like me have attitude and think of farming as old fashioned lifestyle. Because they are eating well that is why they are not taking agriculture serious.

Nevertheless, there is a call for such education to be carried out in a more synchronized and organized way, instead of an informal basis (PAFPNet 2010), as opined by respondents F and J.

Thus respondent J (a local ward councillor) posits that:

> Young people are not motivated as the old people. Due to lack of education in agriculture, people need courses in agriculture to engage young people from schools and teach them the importance of agriculture in our country.

Furthermore providing mentors or exhibiting the success stories of other young farmers and 'agripreneurs' can inspire the youth to adopt agriculture as a career according to respondent K. Additionally, it could aid in overcoming the stigma associated with agriculture as failure-prone and labour-intensive and rather portray the limitless potential of the agricultural sector as a worthy career option (FAO 2014). Novel training methods such as 'sustainable socio-economic entrepreneurship' by incorporating human capacity development (such as cultural, social, technical, organizational and economic) integrate agriculture with industry and services by embracing its wider scope (FAO 2014). Similarly, in the face of increasing food insecurity, the Sustainable Development Goals (the 2030 Agenda) also argue for an integrated approach to addressing food, livelihoods and the management of natural resources (FAO 2016). These approaches help package agriculture as an attractive livelihood option to the youth rather than as an 'old fashioned' activity. Furthermore, they incorporate themes of the green movement, a return to the 'natural', climate issues, political ecology which the youth find 'cool' and á la mode. This contrasts with the mundane lifestyle of the older generation, from which young people wish to flee, as portrayed in the accounts of respondents B, C, D and E.

Conclusion

Understanding from the past through the narratives of the older generation helps in drawing useful insights from the youth's narrative and charting a future for food security and sustainable rural development. As South Africa's population grows and becomes more urbanized, the dynamics of the agricultural landscape also changes which requires skilful human capital to meet the fluctuating consumer needs. Increasing the interest of the youth in agriculture includes revamping the several abandoned agricultural projects on the rural landscape and showcasing the success of thriving young businesses in the sector. This must be coupled with addressing fundamental challenges within the sector related to accessibility to information, finance, land, markets and infrastructure. Enhancing the skill level of the youth will improve their employment opportunities and produce a critical mass of young agricultural entrepreneurs. Another approach to improve job prospects in agriculture would be to build the capacity of the agricultural colleges to escalate the number of skilled-labour training centres. Currently there is an inadequate focus on education to develop skilled labour in the primary agricultural industry. Skilled farmers can be produced by introducing agriculture-related programmes in the school curricula such as the primary and secondary levels whilst modernizing the outdated agricultural curricula. This can also be enhanced with practical training, like repairing and maintaining farming equipment, production capability, farm management and literacy in information technology. There is the need to engage more with the youth in policy development related to agriculture to make such measures attuned to their unique needs. Similarly increased public private partnerships can make agricultural projects constantly relevant to the needs of the market and consumer demands. These measures will develop dynamic communities of practice that will enhance food security and facilitate sustainable development in mountain communities. With the capacity of the agricultural value chain to alleviate the plight of the most vulnerable in society, ultimately the Leave No One Behind concept as per the Sustainable Development Goals (SDGs) becomes tangible amongst those farthest behind.

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Chapter 10
Establishing Multi-Partnerships Environmental Governance in Indonesia: Case of Desa Makmur Perduli Api (Prosperous and Fire Free Village) Program

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Introduction

In 2015, countries worldwide adopted 17 United Nations Sustainable Development Goals (SDGs) with 169 underlying targets that tackle major issues impacting the world. This ranged from ending poverty to protecting the planet and ensuring prosperity for all, as part of a new sustainable development agenda (UN 2015). To reach the goals in 2030, all stakeholders (government, business, and community) need to play their role. The role of government as policy maker is needed to set the target, tracking the progress and evaluating for the future improvement. The consensus among economists and policy makers has grown wider on the need for governments to put forward strong policies directed both at facilitating the growth of existing and emerging industries and addressing the unaccounted and unintended impact on society to growth (PWC 2017). In order to ensure that business takes part in implementing the sustainable development agenda, proactive action should be taken by policy makers.

Note: Exchange rate in 2017: 1 USD~ 13,380 IDR, 1 SGD ~ 10,000 IDR.

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In 2015, the Paris Agreement on Climate Change reflects a commitment to hold the rise in average global temperatures to well below 2° C above (the pre-industrial level) with an aspiration to a lower ceiling of 1.5° C. It too called on parties to “take action to conserve and enhance, as appropriate, sinks and reservoirs of greenhouse gases” as referred to in Article 4, paragraph 1(d) of the UN Framework Convention on Climate Change (UNFCCC) (CoP 2016). The number of companies committing to addressing deforestation continues to increase, in particular the palm oil and timber industries which are directly linked to deforestation.

While SDGs deal more with social concerns such as poverty, healthcare, and employment as well as environmental issues, the Paris Agreement is focusing on environmental concerns. It is expected that private sector will be central to meeting the objectives of both the SDGs and the Paris Agreement. The business community could deliver greenhouse gas (GHG) emission reductions equivalent of 3.2–4.2 billion metric tons of CO_2 by 2030 equal to 7–9% of global emissions in 2010 of which 0.5–1.2 billion metric tons would be delivered by eliminating deforestation.

In terms of loss and damage, the Paris Agreement also recognizes the importance of averting, minimizing, and addressing loss and damage associated with the adverse effects of climate change, including extreme weather events and slow onset events, and the role of sustainable development in reducing the risk of loss and damage. The Paris Agreement builds on the continuation of the Warsaw International Mechanism for Loss and Damage associated with Climate Change Impacts, following the review conducted in 2016 (UNFCCC 2016). Accordingly, areas of cooperation and facilitation to enhance understanding, action, and support may include:

(a) Early warning systems
(b) Emergency preparedness
(c) Slow onset events
(d) Events that may involve irreversible and permanent loss and damage
(e) Comprehensive risk assessment and management
(f) Risk insurance facilities, climate risk pooling, and other insurance solutions
(g) Non-economic losses
(h) Resilience of communities, livelihoods, and ecosystems

The forest fire in Indonesia was considered as a climate disaster due to its negative impacts in terms of GHG emissions, biodiversity loss, health, education, agriculture, water, etc. (Ekaputri 2016). The largest area burnt on the 2015 fire event is palm oil concessions followed by food crops and forestry concessions as shown in Table 10.1. Some of the burnt area was peatland, a global carbon pool (Page 2016). Out of 2.61 million hectares’ land burnt, 618,574 hectares are peatland. This is caused by the emissions from Indonesia’s peatland fires. In 2015 alone, it surpassed GHG from Japan and was more than double in Germany (Tacconi 2016). In total, the GHG emissions during the period July–December 2015 from the fire are 1.75 Gt CO_2, 87% of the total GHG emissions in 2012.

Not so long ago, sustainability was seen by most companies as little more than a peripheral “green issue” — useful for reducing energy and waste disposal cost or

Table 10.1 Area burnt by land use type during the 2015 fire event (Tacconi 2016)

Land use	Area (hectares)	Percentage (%)
Total area burnt	2,611,000	
a. Food crops	346,039	13.25
b. Estate crops	72,763	2.79
c. Palm oil concessions	505,887	19.38
d. Forestry concessions	233,414	8.94
e. Swamp forest	176,179	6.75
f. Natural forest	259,376	9.93
g. Other	807,369	30.92
h. Mining	24,183	0.93
i. Total accounted	2,425,210	92.88
j. Uncontrolled area	185,790	7.12
k. Fire-affected area not allocated to specific stakeholders (e + f + g + j)	1,428,714	54.72

The items a(-)h were obtained from World Bank Report in 2015 on forest fire

supporting some worthy community causes but hardly central to a company's core business (PWC 2015). The palm oil producers for one decade have been accused as one of the causes for the forest fire and deforestation in Indonesia (Purnomo and Dermawan 2017). Forest conservation and palm oil development should be reconciled with the landscape approach. Palm oil businesses have capacity to implementing sustainable development goals through working together in partnership mode with its stakeholders (community, government, other business entities, etc.).

The palm oil itself in terms of area was owned by plantation (private and government owned) 59% and smallholders' farmers 41%. Next to domestic consumption, the export value of palm oil in 2015 is 19 billion US$ representing 12.63% of the country's export. The palm oil industry sustains the lives for 16 million households directly and indirectly. The direct employment in the plantation is six million people (5% of total labor force) using a land area of 11.3 million ha (5.6% of total land area) in 2015 (Detik News 2017). A lot of the fire associated with palm oil is caused by land clearing through slash and burn done by the companies and by individual smallholders' farmers in the neighborhood.

The aim of this chapter is to elaborate the role of a non-state actor such as business partnership with different stakeholders (local community and local government) in reshaping the environmental governance. There are dual functions: (i) preventing forest fire in local scale and (ii) addressing the global issues (climate change, climate disaster, and SDGs) at the same time. We consider the forest and land fire in Indonesia at different levels of governance: global, regional, national, and corporate. We also discuss and analyze the Fire Free Village (*Desa Makmur Perduli Api*) program activities which comprise two initiatives: Fire Alert Village program and Pilot Project Integrated Ecological Farming program. The case study for Fire Alert Village program involves eight villages surrounding the palm oil plantation company (PT AMNL)[1], and the case study for Integrated Ecological Farming program is one of those eight villages on Fire Alert Village program; Lembah Hijau 2 village.

Forest Fire in Indonesia

This chapter will elaborate the forest fire situation within a vertical hierarchy (international, regional ASEAN, national, and local) as shown in the Fig. 10.1. The United Nations task force recommended stronger cooperation between multilateral environmental institutions to facilitate synergies and promote policy coherence (Biermann et al. 2009). This issue has been connected to "institutional framework for sustainable development," i.e., the second theme of the 2012 United Nations Conference on Sustainable Development (UNCSD). A related study has been conducted on the climate change governance in Indonesia (Jupesta et al. 2012).

International Context

Prior to Paris Climate Agreement, the UN held a Climate Summit in 2014 at UN Headquarters, New York. This summit outcome is The New York Declaration of Forests which comprises of commitment to reduce felling of natural forest to half by 2020 and strive to end it by 2030. Attended by governments, companies, indigenous peoples, civil society organizations, and multilateral institutions, this non-binding declaration was the preliminary commitment prior to the Paris Climate Agreement 2015. Several collective actions were announced such as Zero Deforestation

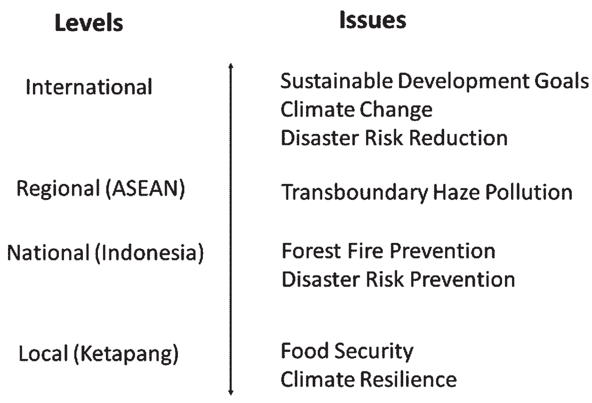


Fig. 10.1 Multi-level governance in forest fire in Indonesia

[1] PT. AMNL is the palm oil company subsidiary of PT. SMART Tbk. PT. SMART Tbk is a subsidiary of Golden Agro-Resources (GAR), the second largest palm oil producer worldwide.

Commitments from Commodity Producers and Traders. Some palm oil companies such as Wilmar International, Golden Agri-Resources, and Cargill pledge to adopt Zero Deforestation Policy from its palm oil production. Beyond that, Golden Agri-Resources (GAR) also makes a commitment that this policy will be applied to all third-party suppliers as well (UN 2014).

The Paris Agreement and the Sustainable Development Goals in 2015 have been set clearly by the governments as the global framework for environment and social sustainability. These two international agreements differ with the predecessor of the SDGs; the Millennium Development Goals (MDGs) are focusing on the developing countries, while the SDGs are applied to both developing and developed countries (CDP 2016). While the Paris Agreement on Climate Change commits the international community to hold the rise in average global temperatures to well below 2° C with an aspiration to a lower ceiling of 1.5° C, the SDGs focus more on both social and environment sustainability.

Out of 17 goals, the goal 13 of the SDGs (–): take urgent action to combat climate change and its impacts – is directly linked with the regional problems that are the subject of this chapter. The goal also acknowledges that the UNFCCC is the primary international intergovernmental forum for negotiating the global response to climate change (UN 2015). Floods, drought, heat waves, and other extreme weather events pose potential losses to persons and communities: losses in life and health, economic damages, displacement, and reduced access to basic needs and services, such as water, food, energy, and education. Disaster risk reduction (DRR) entails systematic efforts to reduce those factors in our societies that amplify the impacts of natural hazards. It includes such actions as building more resilient infrastructures, investing in disaster preparedness and in early warning systems, and developing new tools such as microinsurance and nature-based solutions, among many others.

Regional Context

Rapid land use change and El Niño-Southern Oscillation (ENSO) have resulted in recurring fires in Southeast Asia in recent decades. Frequently the fires then ignite underlying peat soils. The peat fires, in particular, release large amounts of CO_2, along with aerosols and toxic particulates that are known as “haze”. This haze pollution has been a sporadic problem in Southeast Asia over the past 20 years (Lin et al. 2017). They impact most strongly in Indonesia where the forest fire occurred and in neighboring countries Singapore and Malaysia but also extend to Vietnam, Thailand, and the Philippines.

Indonesia’s government has taken a step toward ratifying an ASEAN Agreement on 2014 to fight the haze that reached record highs in the region in that year. Indonesia is the only ASEAN member that has yet to ratify the ASEAN Agreement on Transboundary Haze Pollution, which all other nine country members of ASEAN already signed in 2002 (ASEAN 2015). The pact commits countries to prevent open burning, monitor efforts at prevention, share information, and help one another in tackling the matter. During the haze period on July 2015–October 2015, Singapore faced the worst air pollution index at 341, compared to 50–100 as normal. Singapore Environment Council took action by suspending the use of the Green Label for environmental sustainability given to several haze-linked companies, leading to the removal of these companies' products from some supermarket shelves and increased public awareness of the links between consumer goods and haze (Wijedasa et al. 2015).

Further, in ASEAN Plan 2025, it stressed conservation and sustainable management of biodiversity and natural resources with ten strategic measures. One of these is by strengthening regional cooperation on sustainable forest management in the context of forest fire prevention and control, including through the implementation of the ASEAN Agreement on Transboundary Haze Pollution, to effectively address transboundary haze pollution.

National Context

One of the significant sustainability issues in Southeast Asia is the frequency of forest fire which occurred yearly during the dry season in Sumatra and Kalimantan island of Indonesia. Such fire rages every year during the summer season which brings the haze in most of the Southeast Asian countries: Indonesia, Brunei Darussalam, Singapore, Malaysia, The Philippines, Thailand, and Vietnam. In 2015, due to the El Niño weather pattern, the forest fire becomes especially severe. Unlike other emerging economies, such as China and India, most of Indonesia's GHG emissions are not from industrial activities but from peat fires and deforestation (Jupesta et al. 2011).

While at the global level 57% of the GHG emissions originates from fossil fuel, at the national scale, 53% of such emissions are caused by peat fires and changes in land use and forestry (LUCF) and peat fire (UNFCCC 2018). The total GHG emissions are estimated to grow from 1 Gt CO_2 in 2000 to 1.8 Gt CO_2 in 2014. GHG emissions from peat fire and LUCF have grown from 0.5 Gt CO_2 in 2000 to 0.98 Gt CO_2 in 2014. The GHG emission reduction targets in 2030 for LUCF and peat fire are 59.31% (scenario 1) and 60.15% (scenario 2), while the GHG emission reduction targets for agriculture are 1.1% (scenario 1) and 0.34% (scenario 2). Both scenarios were designed based on the 29% GHG emission reduction within the country effort (scenario1) and further 38% GHG emission reduction with international support (scenario 2).

Most forest fires were caused by the land clearing to convert it into other commodity products, e.g., palm oil plantation. Often this forest fire grows on peatlands, which store carbon from decayed organic matter; in tropical regions, these hold up to ten times as much carbon as surface soil. According to the World Bank, the forest fires in 2015 cost Indonesia 16 billion US$; this amount attributes to 2% of its GDP and is 84% of the export amount of palm oil value itself (World Bank 2016). In terms of SDGs, the Government of Indonesia just enacted Presidential Regulation No.59 in 2017 to promulgate the road map, national action plan, and local action plan to achieve Sustainable Development Goals 2017–2030 (Setkab 2017).

According to the government, 2.6 million hectares of Indonesian land burned between June and October 2015, a land area 4.5 times that of Bali (World Bank 2016). In the absence of the controlled burning measures or significant law enforcement, the fire grew out of control, fed by the drought and exacerbated by the effects of El Niño. This environmental crisis adds to the economic and social growth and costs 16.1 billion US$ (excluding the regional and local cost). Most of the frequent forest fires are in Sumatra and Kalimantan. Numerous studies have reported how Indonesia is lacking measures and efforts related to forest fires; thus multistakeholders' cooperation through multi-partner governance might be a solution to prevent and combat the forest fire.

Over the last decades, there has been rising trend in the occurrence of disasters worldwide and their related economic impact. This is particularly notable for climate-related disasters, − such as drought, floods, and storms (–) which are of signifying concern to agriculture and food security given the sector's dependence on climate. Despite the fact that the severe forest and wildfire during the long-term drought were caused by El Niño (FAO 2016), forest and wildfire has occurred every year during the summer season, mostly caused by land use change (land clearing) (Field et al. 2009). The Fire Alert Village program was developed as an effort to solve the problem of forest and land fire that occurred yearly regardless with or without El Niño.

Corporate Level

To overcome the forest, plantation, and land fire, Golden Agri-Resources (GAR) since 2016 took the initiative by working together with its stakeholders, local community, and local government to implement the "Fire Alert Village" program. This forest fire prevention program was also endorsed by the central government through the Coordinating Ministry of Economic Affairs. Those villages are highly vulnerable for forest fire according to Ministry of Environment and Forestry. Land located in the neighborhood of the company concession will be given priority to being supported by GAR in terms of social and physical infrastructure. There are 731 villages categorized as the most vulnerable villages in terms of forest and land fire according to Ministry of Environment and Forestry. At least three of the most vulnerable villages were located surrounding PT.Agro Lestari Mandiri (AMNL): Sungai Kelik Village, Lembah Hijau 1 Village, and Lembah Hijau 2 village. All of those three villages were in Nanga Tayap district at Ketapang Regency which is in West Kalimantan Province.

GAR decided to implement the Fire Alert Village program on the plantation in Nanga Tayap district due to its historical record. The location which has the highest risk and fire vulnerability level is given the priority for this program. This priority refers to chronology of fire or fire hotspot, land coverage with fire potential, land types (peat or non-peat), land condition and accessibility to the road, river, etc., conflict intensity and land claim, and socio-culture condition of local community which is still using slash and burn in land clearing for production of food crops that underpin food security.

Fire Free Village Program

To prevent the forest and wildfire occurrence, there should be robust and credible mechanisms for engaging multi-partnerships by involving community, market, and state. The study case in this study is the eight villages surrounding the palm oil plantation company (PT AMNL) for Fire Alert Village program and Lembah Hijau 2 village for Pilot Project Integrated Ecological Farming. PT. AMNL was located in Ketapang, West Kalimantan, and it belongs to PT. SMARTTbk., which is one of GAR' subsidiaries.

GAR plantations and most of their operations are in Indonesia consisting of more than 488,000 hectares of palm oil plantations (including smallholder farmers). In 2015, GAR updated its policy governing sustainability and launched the GAR Social and Environmental Policy (GSEP). It covers the key economic, social, and environmental issues facing the palm oil industry and serves as the company's main road map toward responsible palm oil production. In envisioning sustainable progress for people and the planet, it is aligned to the SDGs. As a signatory of the UN Global Compact through its subsidiary PT SMART Tbk., GAR is committed to working on and delivering the SDGs. GAR Sustainability Milestone is shown in Fig. 10.2.

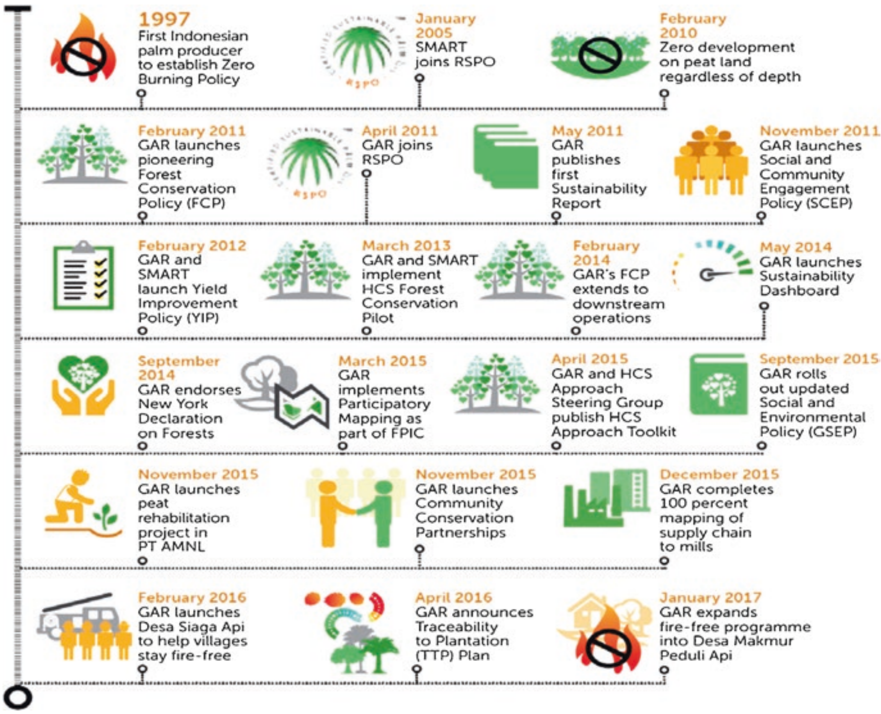


Fig. 10.2 GAR sustainability milestones

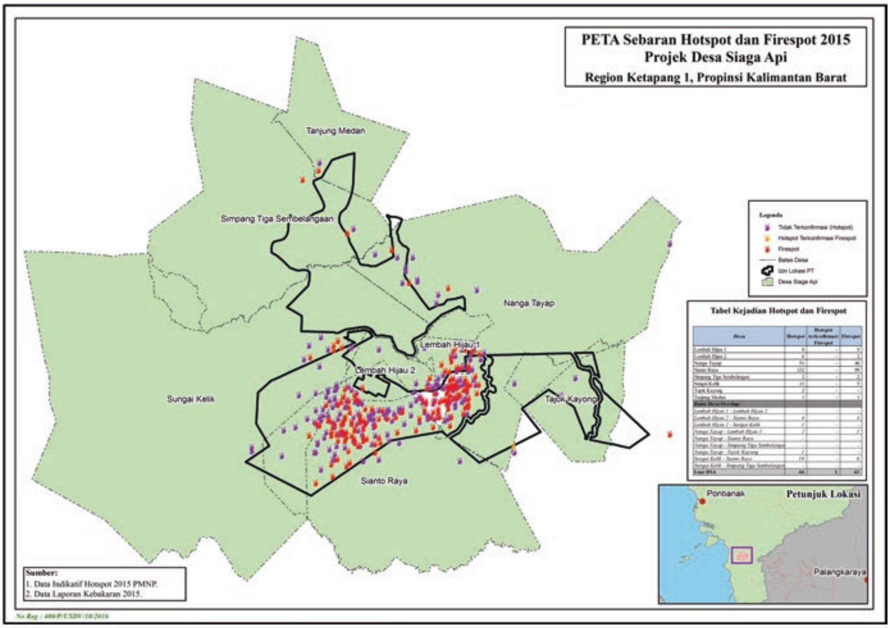


Fig. 10.3 Fires and hotspots on PT AMNL's concession in West Kalimantan in 2015

In 2015, the area burnt at PT. AMNL is 541 ha; which consist of nucleus plantation 450 ha and plasma plantation 91 ha. Figure 10.3 shows the fires and hotspots on PT. AMNL concession in West Kalimantan in 2015. Apart from that, the buffer zone also burnt, as did conservation area 590 ha and area outside of concession 85 ha. Most of the burnt area is peatland. There are eight villages located surrounding PT AMNL: Nanga Tayap, Tajok Kayong, Siantau Raya, Lembah Hijau 1, Lembah Hijau 2, Sungai Kelik, Tanjung Medan, and Simpang Tiga Sembelangaan. All the communities in those villages identify as "traditional agrarian" and still use slash and burn for land clearing.

There are two mechanisms for this "prevent and extinguish" fire program:

1. Build the forest fire prevention and forest fire extinguisher systems within the company PT. AMNL through activities of fire prevention management to prevent the forest fire on community.
2. Community Empowerment Program through implementation of Fire Free Village (Desa Makmur Perduli Api [DMPA]) program.

The first activity was implemented entirely within the company, and the second activity was implemented directly on the entire eight villages that are in the neighborhood of PT. AMNL. The second activity of the Fire Free Village Program consisted of two parts: Fire Alert Community program was implemented on eight villages, and Integrated Ecological Farming program was implemented only in one of the eight villages surrounding company: Lembah Hijau 2 village. Both activities of Community Empowerment Program involved multistakeholders: company, local community, and local government.

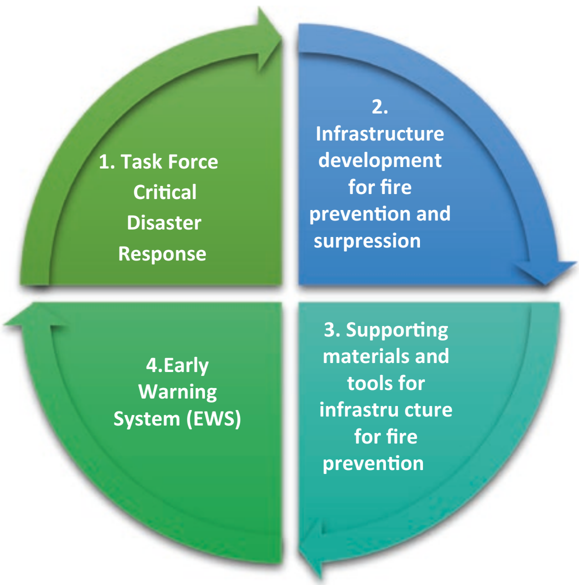
Fire Management System

PT. AMNL (the company) has developed the forest and land fire prevention and suppression system as shown in the Fig. 10.4. There are four systems working simultaneously to ensure the forest and land fire prevention.

*Community Empowerment Program Through Implementation of Fire Free Village/*Desa Makmur Perduli Api (DMPA) *Program*

The Fire Free Village Program started as pilot project in February 2016 as the company's response to the "2015 forest fire." This program works through institutional strengthening (capacity building) at village level, so the villagers are able to organize and coordinate prevention measures and extinguish all fires on forest, plantation, and backyards. This program becomes highly important considering the impact of forest fire to human life in terms of health, environment, social, and economics.

Fig. 10.4 Forest management system within PT. AMNL



Fire Alert Community Program

The Fire Alert Community program was developed on eight villages coordinated by PT. AMNL, with the program implementation stages as shown below:

1. Fire Alert Community inauguration
2. Socialization of Fire Alert Village program
3. Mapping of village border indicative
4. Formation and institutional strengthening of Fire Alert Community
5. Provision on infrastructure and equipment for Fire Alert Community (FAC)
6. Development of early warning system for forest and wildfire prevention
7. Socialization and campaign on forest and wildfire
8. Pilot Project of Zero Burning Land Clearing (ZBLC)
9. Monitoring, evaluation, and reward for Fire Alert Village

Integrated Ecological Farming Program

The aim of this is to enhance the community capacity to sustain its food without land burning. Land clearing by burning is ecologically unsound not only impacting the ecology and degrading the land's support systems over the long term but may also trigger forest and wildfire disaster. To meet the primary need for food, the Integrated Ecological Farming was developed as implementation of an agricultural system based on Zero Burning Land Clearing (ZBLC) method. Integrated Ecological Farming was promoted (mainly through Farmer Field Schools and Extension) as an alternative technology for the traditional farmers, many of whom practice the tradition of cut/slash/burn. The field school demonstrated how to self-sustain farming without using chemicals. It showed that there is an expenditure reduction when using improved farming practices to grow the self-sustaining vegetables on the backyard. These crops provide food security to the family through "own use," and any surplus can be sold to generate revenue and improve household incomes (Box 10.1).

The pilot project for Integrated Ecological Farming program was conducted on Lembah Hijau 2 village in Nanga Tayap district. Lembah Hijau 2 is the village created to accept new settlers under the transmigration program as part of "new Order era." The first phase was in 1992 when people came from Java (Javanese and Sundanese tribes). Most of the households have less than 0.5 ha of land to plant vegetables, raise goats, pigs, cow and tilapia fish. The villagers have one cooperative which is managed by four persons. In terms of education, this village has one kindergarten and one elementary school. There is no medical doctor, but there are two midwives and two traditional healers with two local clinics. There are 259 wells which are in good condition to supply fresh water for the locals.

Box 10.1 Several cases derived from the Integrated Ecological Farming program

Case 1: Mr. Yatimin (60 years old)
Mr. Yatimin is an active member of learning farm Sinar Harapan Besides actively maintaining a learning farm that is used for Farmer Field Schools, he also replicates the knowledge he gained on his backyard. Since January 2017, he started applying the knowledge he gained from field school by planting several vegetable crops (chili, spinach, morning glory, mustard greens, green bean, and corn) using the intercropping method. In a total of 12 months (1 year) in 2017, the 300 m^2garden from Mr. Yatimin produced 23.8 million IDR (~1779 US$). Pro rata in a month, it could bring value from generated additional income and save the household expenses with the amount around 1.98 million IDR (148 US$).

Case 1: Mr. Bambang (34 years old)
Mr. Bambang was a farmer previously. He is an active member of the learning farm Sinar Harapan. Since January 2017, he has planted the chili crop on his 300 m^2 backyard. With 6 plots, it produced 1 kilogram chili plot every week which starts from the third month to 12 months. The chili price is 80,000 IDR per kilogram. Within 1 year in 2017, Mr. Bambang could generate additional income 19.2 million IDR (~1435 US$) or 1.6 million IDR (~119.57 US$) per month.

Results of the GAR Fire Program

The Fire Alert Community program was highly successful as indicated by the decreasing number of hotspots/fire spots from 2015 to 2018 (Table 10.2).

Conclusions

Rapid land use change (including expansion of the area for oil palm production) and El Niño-Southern Oscillation (ENSO) have resulted in recurring fires in Southeast Asia in recent decades.

One of the significant sustainability issues in Southeast Asia is the frequency of forest fire which occur yearly during dry season in Sumatra and Kalimantan island of Indonesia. The forest fires in Indonesia are considered as climate disasters due to the negative impacts in terms of GHG emissions, biodiversity loss, health, education, agriculture, water, etc. Indonesia's government has taken a step toward ratifying an ASEAN Agreement on Transboundary Haze Pollution, which all 10 members

Table 10.2 Hotspots and fire spots in 2015–2018

		2015		2016		2017		2018	
No	Villages	Hotspot	Fire spot	Hotspot	Fire spot	Hotspot	Fire spot	Hotspot	Fire spot
1	Lembah Hijau 1	8	9	0	0	0	0	1	1
2	Lembah Hijau 2	6	2	0	0	0	0	1	1
3	Nanga Tayap	51	40	13	0	3	0	3	2
4	Siantau Raya	132	99	2	0	3	0	6	5
5	Simpang Tiga Sembelangaan	2	2	1	0	1	0	13	3
6	Sungai Kelik	11	5	2	0	3	0	13	4
7	Tajok Kayong	2	0	4	0	2	0	–	–
8	Tanjung Medan	1	1	1	0	0	0	–	–
	Total	213	158	23	0	12	0	37	16

already signed in 2002 (ASEAN 2015). The total GHG emissions are estimated to grow from 1Gt CO_2 in 2000 to 1.8 Gt CO_2 in 2014. GHG emissions from peat fire and LUCF grew from 0.5 Gt CO_2 in 2000 to 0.98 Gt CO_2 in 2014.

To overcome the forest, plantation, and wildfire, Golden Agri-Resources (GAR) since 2016 took the initiative by working together with its stakeholders: local community and local government implementing "Fire Alert Village" program. The study case reported here involves eight villages surrounding the palm oil plantation company PT. AMNL located in Ketapang, West Kalimantan, and it belongs to PT. SMART Tbk., a subsidiary of Golden Agri-Resources (GAR) company, one of the largest palm oil companies in the world. The Fire Free Village (*Desa Makmur Perduli Api)* program consists of three activities: Fire Management System, Fire Alert Community program, and Integrated Ecological Farming program. The Fire Management System was implemented within the company and fully organized by the company itself. The Fire Alert Community program was developed through community engagement to prevent the fire by formation of the Fire Alert Community.

The Integrated Ecological Farming program was socialization to the local community for noslash and burn by Zero Burning Land Clearing (ZBLC) by the development of the Field School. The success indicator of the Fire Alert Village is the reduction of the hotspots/fire spots, while the success indicator for the Integrated Ecological Farming is the replication on the backyard from the Field School participants.

The case study on the Fire Alert Community program shows that forest fire risk can be reduced, so that people could realize the healthy environment which is free from fire and haze. The hotspots were successfully reduced from 213 in 2015 to 37 in 2018, while the fire spots that were not detected by satellite were decreasing as well from 158 to 16 within the same period. The participation of local government as facilitator for the training and socialization, the funding from the company, and the active engagement from the local community in the fire prevention training and socialization could bring about prevention of fire and avoid a lot of loss and damage.

In Indonesia, the food production was highly impacted due to the climate change. The crops productivity has declined in 2015 due to long drought caused by El Nino. This is also exacerbated by burning the land as local tradition to clear the land before planting. The local community in Kalimantan believe that fire is the most effective tool in the existing practice of shifting cultivation that existed for hundreds of years. Shifting cultivation is local wisdom where the plot of land was cleared through fire and later cultivated to produce food crops for 1 and 2 years before moving to another plot. In this old technique, only man power alone could be used without machinery for cultivation, and no chemical fertilizer was applied. However, this shifting cultivation technique has a high risk in terms of generating uncontrolled fire that could be expanded by wind over a broader area within several hours, especially in the drought season. The productivity of this technique of food production is also relatively low compared with the modern agriculture techniques that rely on machinery and chemical fertilizer.

Hence, there is an urgent action to invest in healthy environment that produces food in sustainable way. One of the solutions is by engaging the community to Zero Burning Land Clearing. It would bring enormous impact to the environment so as enhance the food security. Food security and livelihood of the poor were vastly improved by adoption and replication of integrated ecological farming approaches into the community's backyard.

The two case studies for the successful replication on integrated ecological farming illustrate the merits of intercropping method over monocropping. Crop diversification is an important climate change adaptation and vulnerability reduction strategy that can, in the context of climate variability and extremes, help distribute risk, increase productivity, and stabilize incomes of the smallholder farmers, thus leading to food access improvement. This crop diversification that was implemented by Mr. Yatimin brought 25% more value added in terms of economic benefit compared with monocropping that was implemented by Mr. Bambang.

Before the pilot project Zero Burning Land Clearing, this area faced high prices of food since most of the food comes from outside the region. Since 2016, the food price was becoming more affordable since this program of backyard food production could fulfill (partly) the community food supply. This GAR program has been successfully accomplished with multiple benefits: (i) reduction of both forest fire and wildfires and (ii) strengthening resilience in terms of food security and poverty alleviation. It is envisaged that this program Fire Free Village (*Desa Makmur Perduli Api*) will be replicated and become a "lesson learned" on how the stakeholder cooperation could bring positive impact to realize climate resilience and mitigate climate change toward Sustainable Development Goals (SDGs).

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Chapter 11
From Zero-Acreage Farming to Zero Hunger in African Cities: Some Possibilities and Opportunities

Aliyu Salisu Barau

Context and Setting

Hunger and malnutrition have remarkable presence in many African regions including the fast-growing urban areas. Unfortunately, urban agricultural lands are progressively declining due to rapid urbanization and urban environmental quality decline. Amidst global food bounty, there is widespread malnutrition and poor nutrition which is responsible for undernutrition, stunting and obesity (Webb et al. 2018). Three to four years before launching of the SDGs, it was estimated that about 10% of children under 5 years suffer from acute malnutrition; and about 30% of children all over the world were said to be chronically malnourished (Crush et al. 2012). It is encouraging that many African countries have made significant improvement in reducing stunting, wasting and underweight situation among their under 5 children (Osgood-Zimmerman et al. 2015; Annan 2018). Nevertheless, in spite of this progress, some areas such as drylands of northern Nigeria will continue to experience failure in arresting and reversing stunting among children. This is because it has been observed that poor nutrition is responsible for the recent rise in the number of underweight adult females (Webb et al. 2018). Most of the previous studies identified interventions made by international development aid agencies and national governments and in this way obviously ignoring the potential roles of households in eradicating hunger and malnutrition.

Recently, the UN agencies, development partners and the African Union endorsed the Bellagio Communique which stressed the need to integrate urban food system into spatial planning, land management and enhancing human well-being (UN Habitat 2017). Such initiatives can help African urban agglomerations to fast track implementation of SDG 2 (zero hunger) and SDG 11 (sustainable urbanization).

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Indeed, social scientists have underscored the need to pay attention to urban transformations and role innovation in addressing contemporary urban challenges (Caprotti and Cowley 2017).

The United Nations has projected that between 2018 and 2050 India, China and Nigeria will account for 35% of the global urban population. India is expected to add 416 million urban dwellers, China is to add 255 million, while Nigeria's urban population will reach 189 million (UN DESA 2018). Such figures may seem daunting; however, they could also provide some opportunities that can come through innovation in urban land use. For instance, to feed the exploding population, it is imperative to diversify nutrient-rich food production strategies (Hunter et al. 2016). Perhaps, one of the best ways to achieve this is through paralleling with SDGs and relevant targets and indicators set for implementing zero hunger. At the level of urban areas, this can be achieved through innovative policy formulation and advocacy (Gore 2018). It can create an enabling environment.

The role of preindustrial urban areas in the production of rich diets is not unknown. Urban households contributed significantly to food security in cities and towns of ancient Maya and Byzantine (Barthel and Isendahl 2013). In many cases, urban agriculture has proved to be a dynamic food production system (Binns et al. 2003; Ambrose-Oji 2009; Olaniyi 2012; Maconachie 2013; Mukundi et al. 2014). Nevertheless, many African cities are undergoing transformations in their social, institutional, economic, spatial form and governance dynamics. Such changes affect traditional land-based urban food production traditions due to declining spaces for agriculture, pollution and land conversion (Binns et al. 2003; Barau et al. 2015). Whereas some studies have documented Western and Asian cities' robust urban household gardening systems that support family nutrition (Barau 2015; Barau and Kafi 2017), less is written about such practices in the sub-Saharan African cities.

Challenges and Opportunities in African Urban Food Production

Urban agriculture (UA) in Africa with its uncertain land tenure security is also facing the threats of disappearing spaces and contaminated water, particularly in the case of irrigated sites. For instance, soils in some gardens around Kano city in Nigeria, Bobo-Dioulasso in Burkina Faso and Sikasso in Mali were contaminated by heavy metals – cadmium, copper, lead, chromium, zinc, nickel, etc. (Abdu 2010). The results of a survey conducted by African Food Security Urban Network (AFSUN) revealed that more than 60% of the households in cities of the poor southern African states were severely exposed to food safety issues (Frayne et al. 2014). Indeed, the dependency of farmers on urban wastewater (Binns et al. 2003; Adedeji and Ademiluyi 2009; Dawaki et al. 2015) is a strong justification for urban policymakers to give due priority to ZFarming as a strategy for production and consumption of hygienic and nutritious foods at household scale.

In many African countries, the spaces used for urban agriculture range from a single pot for a single plant to plots around houses, areas along streams, unused lowlands and valleys, vacant plots, public open spaces and utility service areas (Drescher et al. 2006;Neergaard et al. 2009). In spite of their importance, these food production systems are hardly integrated and documented by urban planning institutions. Hence, they are always at the receiving end of rapid urban growth in sub-Saharan Africa. Indeed, Africa has rich plant diversity estimated to be around 40,000 of both local and naturalized species (Maundu et al. 2009). However, only up to 1000 species are used as vegetables. Thus, it is apparent that Africa's biodiversity offers high potentials of nutritional foods. In spite of this potential, it is estimated that Africans can only consume less than 50% of the recommended 73 kg per person per year (Yang and Keding 2009).

A study conducted in South Africa revealed that leafy foods grown in household gardens enhance families' easy access to provitamin A-rich foods (Faber et al. 2002). Household food security is achieved when any given household is able to access the needed quantity, quality, safety and cultured defined food needed by all its members – United Nations Administrative Committee on Coordination-Subcommittee on Nutrition (UN/ACC/SCN 1991).

The Challenge of the New Urban Age

In response to the challenges of the new urban age, Ingersoll (2013) coined the term *agricivismo* which means 'civil agriculture' to underscore the potentials of cities in producing different scales and genres of food production. Related to this, the concept of zero-acreage farming (ZFarming) is a kind of integrated farming using urban open spaces (Specht et al. 2014).Variants of ZFarming include rooftop gardens (RTGs), edible green walls, sky farming and vertical farming (Specht et al. 2016).

Such innovative practices are needed in African cities as a means of supporting food and environmental security. Taking West Africa as an example, it is estimated that by 2020 more than 60% of the subregion's population would live in urban areas (Cofie 2009). Added to this is the fact that more than 70% of Africa's urban dwellers live in slums where hunger and malnutrition are part of the poverty circle (Garvelink 2014). At the same time, cities in some African countries have become destinations of displaced women and children who often lack access to food and nutrition (Barau 2018). Some scholars explained the linkages between urbanization, urban nutrition and food security in Africa through demographic, epidemiological and nutritional transition and the double burden of malnutrition theories (Mohiddin et al. 2012). Indeed, these theories are pessimistic in nature, as such, scholars, policymakers and civil society need to craft new framings and initiatives that support a kind of urban households' nutritional transformation.

There are already opportunities to explore and exploit as far as introducing ZFarming for African urban dwellers is concerned. For instance, Neergaard et al.

(2009) reported that 80% of the residents of Libreville in Congo practice horticulture and about 50% of households in Ghana's capital city of Accra are engaged in subsistence farming. Most of these cities, known for successful urban agriculture, are located in the wetter tropical parts of Africa where rainfall and access to flowing rivers and ponds keep them growing. Another issue that is being ignored is the cultural and gender dimensions of urban agriculture. For instance, in some cities in Malaysia, households of different racial and religious backgrounds produce vegetables that meet their basic needs for culinary, esthetic and spiritual purposes (Barau 2015). Drawing from experiences of many developing countries, Drescher et al. (2006) observed that both household and allotment gardens in cities need to be supported by an institutional paradigm shift and to adopt urban planning choices. Much has been written on urban agriculture in Africa but not much on the disconnect between urban agriculture potentials and urban planning. Indeed, most studies on the success of ZFarming come from developed countries of North America, Asia, Europe and Australia (Thomaier et al. 2014).

Assessing the Response to the Challenges

In response to these challenges, this chapter explores possibilities and opportunities of adapting ZFarming as a vehicle for combating hunger, malnutrition and climate change impacts. The focus of the study is Kano city which is Nigeria's second largest urban agglomeration. The research questions that drive this study are as follows: Can ZFarming support urban resilience in rapidly urbanizing countries? Which plants can households grow to eradicate hunger and malnutrition?

Study Area: Site Selection and Rationale for the Study

The study area covers the old walled city of Kano and its peripheries which are exposed to rapid urbanization at the expense of agricultural areas (Fig. 11.1). The natural vegetation of urban Kano is classified as Sudan savanna of sparse and medium height trees that have been transformed into a derived savanna region (Barau et al. 2015). Its tropical wet and dry climate is characterized by seasonal rainfall (April–October) with a mean annual temperature of 30°C. Thus, the area falls within West African drylands which is characterized by erratic rainfall. The nature of peri-urban agriculture in Kano has attracted the attention of researchers because of its sustainability dynamics documented in many studies (Lynch et al. 2001). According to Mortimore (1993), peri-urban agriculture in the semiarid Kano is characterized by the culture of trees, livestock and crop management, on and off farm labour and seasonal migration. This culture of sustainable food production is currently threatened by a massive urban growth in and around Kano and changing climate (Maconachie 2007). The city is a large market for consumption of a variety

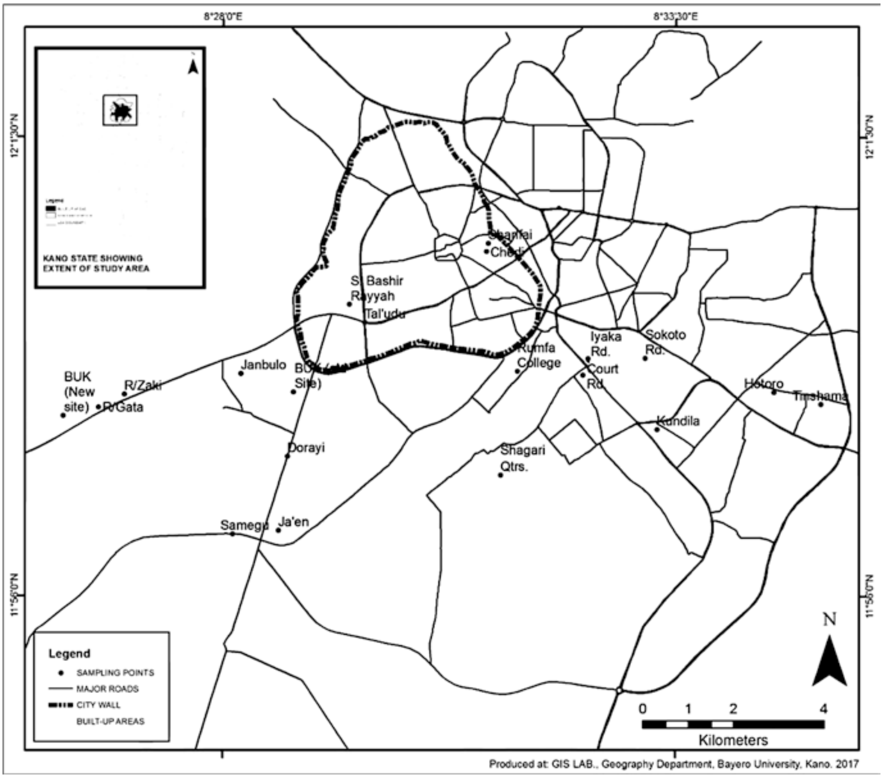

Fig. 11.1 Sites of observations of house gardening among middle-class population in urban Kano

of agricultural produce such as fruits, grains and vegetables (Gambo 2016). Another critical challenge for urban agriculture includes instability in product pricing, declining farm size and soil erosion (Dawaki and Shu'aibu 2014). Urban agriculture in Kano remains largely informal and unplanned, mainly practised by rural migrants, refugees, vulnerable groups and illiterates (Buerkert et al. 2009). Nonetheless, the situation in the study area makes farming a good alternative for provisioning of nutrient-rich foods in this dryland city.

Methods

This study design involved two main methods that helped the researchers to identify pathways for achieving SDG-2 – Zero hunger and improved source of nutrient-rich foods. Thus, the method applied was Delphi technique supported by the second method of field-based observation of existing household gardening practices. Social scientists and scholars from other disciplines have employed the Delphi technique to construct future scenarios (Keller 2001; Kent and Saffer 2014). This method is praised for its ability to overcome risk of peer influence and intimidation (Thangaratinam and Redman 2005). There is no fixed number of experts for Delphi participants although many studies used ten or more experts (Toepoel and Emerson 2017).

Thus, we identified and selected 11 experts all of whom were experienced university lecturers with different disciplinary backgrounds and higher degrees in the following disciplines: Agricultural Economics, Architecture, Estate Management and Valuation, Environmental Management, Geography (climatology), Urban Planning and Quantity Survey. Only 3 out of the 11 participants were female. This multidisciplinary team participated in the two rounds of the Delphi survey conducted for the study. The selected experts were deemed easier to track and get them involved in the rounds of the survey. The questionnaire has a total of 12 questions out of which 6 were open-ended and the remaining 6 were close-ended questions.

The questions centred on the following variables: profession/discipline of the expert, complementarity of ZFarming to land-based farming, public well-being, benefits to urban environment, plant for use in urban ZFarming, role of architecture and planning, location suitability, types of buildings and structures for Zfarming, prospects of ZFarming and ZFarming and future resilience. The questionnaire also asked questions on feasibility of ZFarming in the city for food cultivation on rooftops, balcony, façade, walls, pots and other spaces. The experts ranked these potential spaces on a scale of 1–5. The mean of these values was computed for the city. Following the first round of the survey, the responses were compiled and summarized and resubmitted to the participants, and all of them endorsed the summary of the views expressed by other respondents. Hence, the results of the second round were considered adequate and reached experts' consensus making the second round of the survey conclusive. As a qualitative study, the narratives elicited from the individual experts were analysed using an online text analysis software, namely, Textalyser (http://textalyser.net/).

The software helped with a quantitative and qualitative analysis of the text that emanated from the experts' narratives that were summarized and entered into the tool. The software analysed the text narratives identified by each of the participants which were grouped to form a summary of their expressed views. In view of the length of tables generated, it became necessary to tweak the results for convenience and relevance. For example, a table of unfiltered words generated by the Textalyser was converted into a word cloud using Word It Out facility (https://worditout.com). This follows van Dijk's argument that context is built based on appropriateness, relevance, dynamism, planning and context control.

As per the second method, Caprotti and Cowley (2017) observed that it is imperative to understand urban crises normatively and innovatively. Thus, researchers can use experiments to understand issues such as climate change crisis and urban resilience dynamics through innovative and transformative pathways. For instance, SDG Labs are being used as vehicles for implementation of innovative ideas and projects for actualizing SDGs (Strain 2017).

In order to support the Delphi survey, we embarked on fieldwork to find out the Strength, Weakness, Opportunities and Threats associated with zero-acreage farming in the study areas. We conducted our observation during the peak dry season (February–March) in order to identify the best strategies for household gardens at the peak of the dry season.

This study focused on an important population segment, namely, the middle class, which is considered to be the main agent of change and transformation in Africa (Melber 2016). Since specific data on this group is not provided in the Nigerian census, we identified houses of senior staff of public agencies and entrepreneurs located across urban Kano through convenient sampling. The sampling points covered 17 houses located in planned areas of the city (and other planned layouts), the old city, unplanned areas and houses located within institutional buildings such as university campus, schools and hospitals (see Fig. 11.1). In each case, one member of the household was interviewed on the types and quantity of plants available and estimate of fruits and vegetables produced. Other questions of the interviews included how the plants were maintained by household members and how they were used by the households. The information obtained from the interviews was used to determine fruits and vegetables that households grow in the study area.

Results

Analysis of Experts' Language on ZFarming

The summary of the experts' views on ZFarming as shown in Table 11.1 was highly technical and diverse considering its high Gunning-Fog Index which suggests use of jargon by the experts from various academic disciplines. As such, technical jargon such as the ones used by the experts may not be clear or understandable by the public and policymakers. For instance, the use of the word 'albedo' for surface reflectivity is more familiar to climatologists than quantity surveyors. Hence, it is the duty of the experts to simplify some of the technical jargons in the best ways to make them understandable to the public and policymakers.

Table 11.1 Characteristics of experts' linguistic expression

Total key words count	144
Number of different words	88
Complexity factor (Lexical density)	61.1%
Readability (Gunning-Fog Index) *(6-easy 20-hard)*	39

Experts' Opinion on ZFarming

The experts' response to the close-ended question on both rounds of the survey endorsed statements on feasibility of ZFarming in urban Kano or its complementarity to land-based agriculture. Table 11.2 reveals the top words used by the experts, for example, while 'yes' implies experts' overall positive stand on ZFarming in urban Kano, words such as 'enhance' and 'improve' implied the consensus among the experts on the gains and prospects of ZFarming as a strategy for climate adaptation in urban Kano. Other words also implied the importance of other factors in supporting development of ZFarming in urban Kano.

Phrase Prominence in Expert's Expressions on ZFarming

What is given in Table 11.2 becomes clearer in Table 11.3 which outlines the key phrases used in the expert's narratives. The software recognize 'yes' as a phrase because it can have a full meaning. In this study, 'yes' was used by the experts to show their endorsement of ZFarming in a high percentage which suggested strong consensus. For instance, the words 'Kano old city' were featured as a prominent phrase because all the experts believed ZFarming would be very suitable and doable there in spite of high population density, traditional architecture and informal planning. The experts projected some of the benefits of ZFarming for Kano to include 'improving' and 'enhancing' food security, air quality and job creation.

Mean Scores for Spaces for ZFarming Feasibility

Experts identified spaces for feasibility of adapting ZFarming in urban Kano. The experts' opinions varied as regards suitability of different parts of the city. Apparently, the experts' ranking suggested that planned areas are most suitable for ZFarming in Kano city and its surroundings (Table 11.4).

Table 11.2 Word rankings based on experts' expression as summarized and analysed

Word	Occurrences	Frequency	Rank
Yes	37	25.7%	1
Improve	3	2.1%	2
Buildings	3	2.1%	2
City	2	1.4%	3
Food	2	1.4%	3
Family	2	1.4%	3
Nutrition	2	1.4%	3

Table 11.3 Prominent phrases in the expert's narratives

Expression	Expression count	Frequency	Prominence
Yes	36	23.7%	88.5
Old city	2	1.3%	40.1
Food security	2	1.3%	43.1
Job creation	2	1.3%	46.1
Air quality	2	1.3%	68.4

Table 11.4 Experts' scores for spaces for adapting ZFarming in selected sites in Kano urban agglomeration

Sites/spaces	Rooftop	Balcony	Façade	Walls	Pots	Others	Mean score
Old City	24	23	15	20	40	20	125
Nassarawa GRA	40	40	50	48	50	30	233
Institutional buildings	36	26	52	40	40	30	199
Planned layouts	20	38	48	36	50	18	195
Housing estates	45	35	20	38	40	34	185
High-rise buildings	20	44	28	40	48	38	186

Source: experts' survey

Fruits and Vegetables Grown by Households in Kano

Table 11.5 presents the results of field observations and the interviews with households and the plants cultivated in the household areas and their uses. It is important to note that both climate and soil condition are suitable for growing a goodly number of edible plants of high nutritional values. The plant products are used for different purposes. For example, although cassava is a high-carbohydrate tuber, its leaves are used in making soup. Indeed, types of plants grown in the city can be seen as an indicator of the strengths and opportunities of the city.

Another important issue is that household members' interests and knowledge of social, ecological and economic importance of plants significantly determine the amount and quality of plants that households can raise. For instance, the current study found that some professors residing in the Bayero University cultivated as many as 25 varieties of fruits and vegetables within their house yards of approximately 200× 200 m^2. On the other hand, a respondent observed that while his house garden could produce most of his household vegetables' needs, most of his neighbours did not plant gardens.

At the other middle-income class houses located in planned and unplanned parts of the city, the study found an average of 13 plants both on ground and in pots. However, some households do not have any plants despite the availability of spaces. Out of the 17 households selected for observation, 5 of them lacked any plants. Households in non-institutional residential areas lacked sizable land to cultivate. This is because most surfaces are sealed with concrete, tiles and other forms of

Table 11.5 Plant products (fruits and vegetables) as observed from experimental households

	Name of plant	Common uses by households
1	Date palm	Eaten raw
2	Guava	Eaten raw, fruit salad, juice
3	Banana	Eaten raw, fruit salad, juice
4	Ginger	Spices, drink
5	Spinach	Soup
6	Pawpaw	Eaten raw, fruit salad, juice
7	Onion	Soup, stews, beef
8	Sweet potato	Salad, cooked
9	Lemon	Eaten raw, fruit salad, juice
10	Sorrel	Soup, stews
11	Cassava	Raw or roasted
12	Jute plant	Soup, stews or as leafy food salad
13	Carrot	Eaten raw, fruit salad, juice
14	Okra	Soup, stews
15	Pumpkin	Soup, stews
16	Groundnut	Raw or roasted nut
17	Bambara nut	Raw or roasted nut
18	Tomato	Soup, stews, salad
19	Green beans	Leafy food salad
20	Melon	Eaten raw, fruit salad, juice
21	Lettuce	Salad
22	Sugar cane	Eaten raw or juice
23	Soy bean	Soya cake, soy milk, stew
24	Rose flower	Tea aroma
24	Moringa	Leafy food
25	Pomegranate	Eaten raw
26	Grape	Eaten raw or dried
27	Sea almond	Raw fruit, seed as nut

sealing materials. When asked about potential spaces for pots or use of part of the building, their response was that they thought growing vegetables would not yield anything much for their satisfaction. Another respondent argued that he would ‘incur expenses of raising wood structures for plants that would not give him much food or money’.

Overall, our observations revealed that the ratio of edible plants to inedible plants in the study area is on the average of 1:5. Most of the inedible plants are; exotic flowering plants. Examples of fruits and vegetables grown in the study area are shown in Table 11.6, Fig. 11.2, respectively. As observed and verified by respondents, household members water their plants with pipe-borne water during the dry season (October to May). This is therefore one of the main threats and weaknesses associated with household farming in dryland cities.

Results given in Table 11.6 imply that a few households only produce a sufficient amount of fruits and vegetable to satisfy their nutritional needs, while others hardly

Table 11.6 Fruits and vegetables production and nutritional needs following FAO's recommended intake for the 12 sampling sites (the remaining 4 sites lacked plants)

Sampling sites	House size (M^2)	Number of people living	Number of crops grown	Estimated harvested crops (Kg/year)	Total nutritional need of people (Kg/year)	% of satisfaction of the nutritional needs
1	60	5	13	290	365	79
2	200	11	22	1800	803	224
3	100	8	12	350	876	39
4	70	4	15	50	292	17
5	150	10	16	400	730	54
6	50	12	03	35	876	4
7	50	13	06	200	940	21
8	40	5	14	150	365	41
9	50	8	11	30	584	5
10	120	5	16	800	365	219
11	70	3	12	120	210	57
12	50	5	16	50	365	14

Source: fieldwork 2017

Fig. 11.2 Some of the vegetables grown in urban Kano are exotic plants with high nutritional and calorific values for the urban populace

produce what can satisfy the needs of one person. It is apparent that there is a strong link between household number, interest in gardening and food production. Some of the households can produce in excess of their basic annual needs of calories/nutrition from their habitat. One of the respondents – a professor (–) claimed that he cultivated all the onions, soy bean, guava and all leafy foods that his family of 11 persons need in a year. In contrast, since plot size in residential areas in the old city and planned areas are smaller, the chances of producing high quantities of fruits and vegetables are lower. However, this creates an opportunity for utilizing pots, walls, verandas and other available structures for growing fruits and vegetables.

Our results, indicated that in 14 out of the 17 selected sites, male household heads usually take care of the gardens. Women pay little attention to growing fruits and vegetables. Five respondents noted that from their experience women prefer to take care of flowering plants and flower pots for their aesthetics.

Some of the fruits and vegetables grown by households are shown in Fig. 11.2. We observed that none of the sites of study operates scientific and innovative gardening techniques. Similarly, most of the households did not perceive the importance of social, ecological and economic benefits of home agriculture and gardening.

Discussion and Conclusions

This section outlines the study implications and key messages emerging from this chapter. By focusing on ZFarming, it becomes clear that this strategy may help rapidly urbanizing African countries to avert acute hunger and nutritional deficiencies. In addition to that, the co-benefits of this strategy may include climate actions and resourceuse efficiency in dryland cities. The main messages emerging from the study are explained in the following paragraphs.

A good number of studies reveal that lands for urban agriculture in dryland cities have progressively declined over time (Binns et al. 2003; Maconachie 2007; Dawaki et al. 2015). Incidentally, the population of urban areas in drier parts of Africa keeps increasing bringing problems of malnutrition and food insecurity including the challenge of child stunting. This situation justifies the urgency for a policy response to facilitate adoption and promotion of ZFarming as an alternative means of improving urban nutrition and environmental sustainability. Urban sustainability stakeholders and healthcare practitioners are duty-bound to formulate policies and advocacy for integrating ZFarming into integrated implementation of SDG-2 and other relevant policy initiatives.

The selection of the middle class as a representative group to understand the possible transition to a ZFarming garden city also proved to be relevant. Middle-class households can cultivate enough nutrient-rich foods – fruits and vegetables (–) within their homes because they currently inhabit areas that were previously used as farmlands. Therefore, it becomes imperative for governments and civil society groups to shift attention to households as a nucleus for combating hunger and malnutrition through ZFarming. This strategy is vital for offsetting and trading off urban land conversion impacts.

One thing that comes out clearly from this study is the role of urban planning in promoting urban food security. The most productive areas, as found through field observations, are the planned areas, and this was also confirmed by the experts' ranking where planned areas scored the highest potentials. Nevertheless, it is important to initiate innovative urban planning and upgrade projects that introduce ZFarming into informal areas and slums which are occupied by the poor, malnourished children, women and other vulnerable groups. One of the marked differences with most global regions is that pots appear to have the highest potentials for

ZFarming in the study area. Indeed, pots can be used easily by the poor, the rich and the middle class for growing vegetables.

The current study noted poor participation of women in home gardening. The reason is likely linked to lack of awareness of the multiple benefits of home gardening. Some women also have more preference for flowering exotic plants. Indeed, the participation of women is critical to achieving long-term combating of land degradation and greening of African cities. This situation is strongly different to that in Malaysia, where women actively participate in growing vegetables (Barau 2015). Thus, ignorance among women is threatening nutrient-rich food security.

This work provides empirical evidence on the strengths of adopting ZFarming as well as some opportunities, threats and weaknesses in climatically vulnerable African cities. Ecological benefits include enriching biological diversity in residential areas. It may also enable households to save some amount of money when they cultivate fruits and vegetables from within their homes. Again, depending on the size of a given household, families may be able to grow basic needs of some vegetables and fruits. In this way, many households may be able to fulfil or complement the recommended intake of 73 kg per person per year (Yang and Keding 2009). ZFarming creates a chance for households to enjoy environmentally clean agricultural products that are fresh and free of chemical pollution. Furthermore, products grown within premises of residential areas have a lower-carbon footprint compared with those produced from distant places, transported into the city and reaching consumers' homes.

It is essential that planners, policymakers, scientists and practitioners such as gardeners, primary healthcare personnel and landscapers work together to define strategies for supporting and upholding a viable strategy for meeting milestones of implementation of SDGs.

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Chapter 12
Land User Perceptions of Organic Farming Practices That Can Combat Drought and Land Degradation Through Efficient Use of Land and Water

Shafiqul Islam

Context and Setting

Land is the essential resource on the earth. The land has been given importance in Sustainable Development Goal 15 (SDG15), Life on Land. Vlek et al. (2010) defined land as the collection of soil components, biotic components, landscape and climatic aspects.

Land plays a significant role in producing food. Land is also a means for conserving biodiversity, regulating hydrological regimes, recycling soil nutrients, and sequestering carbon. Land and fertile soil are the most important physical natural resources for agricultural production and livelihood activities. Douglas (1994) mentioned numerous land degradation factors such as soil degradation, vegetation degradation, water degradation, climate deterioration and industrial development. Soil degradation is related to the capacity to lessen soil productivity, leading to soil erosion and changed soil properties. Vegetation degradation diminishes vegetation and ground cover. Water degradation is an acute crisis of surface and groundwater resources in terms of quantity and quality. Climate deterioration affects climatic conditions that increase challenges and crop risks. Industrial development and urbanization are encroaching and agricultural land is being converted to industrial and infrastructural use.

Bai et al. (2008) reported that a land area of 3.5 billion hectares (globally) has been affected by land degradation processes, affecting 1.5 billion people worldwide in 2005. According to another study, 1.7 billion hectares of land (out of 4.3 billion hectares) in Asia is affected by different degrees of aridity (Sohrab 2015). The United Nations Convention to Combat Desertification (UNCCD) (2015) pointed

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out that 52% of food-producing fertile soils on the globe are classified as degraded land. According to Reddy (2003), direct land degradation costs varied among states from 0.2 to 1.9% of gross domestic product (GDP) with the average being 0.89%. People are affected by drought severely in Asia (UNCCD 2012).

Drought causes land degradation, groundwater depletion and food crises. Soil and land productivity, the groundwater table and food security in the study areas are at risk for climate change issues and faulty land management. Land degradation arising from several causes (see below) is a major problem. The Food and Agriculture Organization of the United Nations (FAO 1993) defined land degradation as a process which lowers the soil's capability to produce goods and services. The degradation proceeds by multiple causes including biophysical and human-induced factors (Orchard et al. 2017). It depends on the scale, context, physiognomy, characteristics and management practices applied to soils and farms. Land degradation is occurring due to both natural and anthropogenic factors. Thirty-eight percent of net cultivable land suffers from organic matter content deficit (Rahman and Hasan 2003). The indiscriminate use of agro-chemicals causes air pollution, soil pollution and water pollution (of both surface water and groundwater). Land degradation is also accelerated by human-induced factors and land use practices.

Problems Faced in the Barind Tract and Consequences

Drought and land degradation cause impacts on agricultural production at the individual, household and community levels. Drought and land degradation are interlinked and have caused huge crop loss in the high Barind Tract. Both natural and human-induced causes are associated with land degradation. Natural causes exacerbated by climatic variability (low rainfall, high temperature), drought and climate extremes lead to land degradation. On the other hand, anthropogenic factors (human-induced causes) including population, land fragmentation, faulty cultivation processes, soil erosion, indiscriminate use of agro-chemicals, cleaning and burning of crop residues in the field, and over-withdrawal of underground water also cause and degradation. Land degradation causes effects on individuals, households and society (low production, low dietary diversity, low nutrition, low income, ill health and poverty). All of these together lead towards food insecurity, low nutrition and ill health (Fig.12.1).

An opportunity arose to evaluate the role of organic farming practices to counter drought effects and arrest and reverse land degradation. Organic farming practices (use of compost, animal manure, green manuring, mulching, zero tillage and plantations) and efficient water use (land zoning) are significantly useful to combat drought impacts on land, water, food security and land degradation process. Organic practices ensure effective strategies for land and water resource management by improving soil properties (porosity, organic matter, soil moisture and fertility); increasing water-holding capacity, infiltration and groundwater recharge systems; reducing runoff; and conserving soil. The indiscriminate use of agro-chemicals also causes air pollution, soil pollution and water pollution (of both surface water and groundwater).

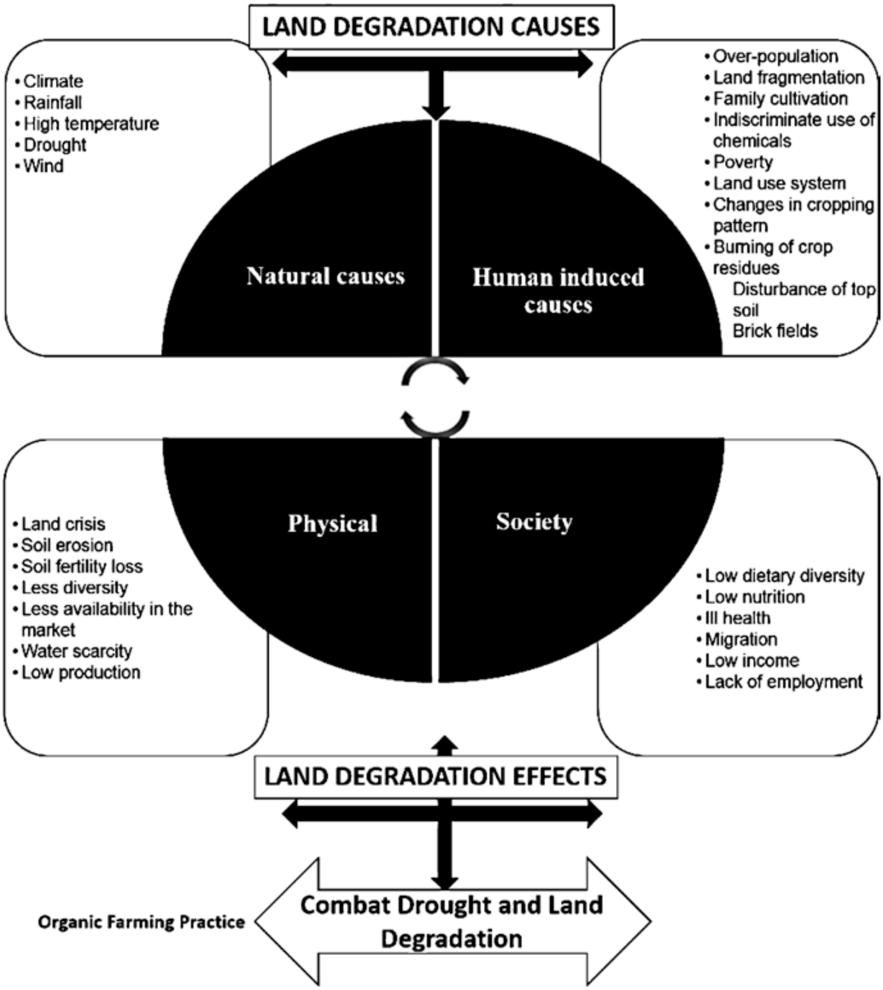

Fig. 12.1 Conceptual framework of drought and land degradation impacts (author's own construction)

Study Area – Attributes and Rationale for Site Selection

The Barind Tract in Bangaldesh (the focus of this study) is the largest Pleistocene-era physiographic unit in the Bengal Basin. It covers most of the Dinajpur, Rangpur, Pabna, Rajshahi, Bogra, and Joypurhat districts in the Rajshahi Division and Rangpur. It lies roughly between latitudes 24°20′N and 25°35′N and at a longitude of 88°20′E. In the Barind Tract, a huge land area, there are two different agro-ecological regions (Table 12.1).

Table 12.1 Areas in two different agro-ecological regions in the Barind Tract

Type of Barind land	Area (thousands of hectares)						
	High land	Medium-high land	Medium-low land	Low land	Total land	Homesteads	Total
Level Barind Tract	151.5	277.7	20.2	10.1	459.5	45.4	504.9
High Barind Tract	148.8	1.6	0.0	0.0	150.4	9.6	160.0

Source: BARC (1989)

Table 12.2 Drought-prone areas in Bangladesh by cropping seasons

Cropping season	Drought-affected area (millions of hectares) and type					
	Very severe	Severe	Moderate	Mild	No drought	Non–T. Aman rice
Rabi	0.446	1.71	2.95	4.21	3.17	–
Pre-kharif	0.403	1.15	4.76	4.09	2.09	–
Kharif	0.344	0.74	3.17	2.9	0.68	4.71

Source: Karim and Iqbal (2001)

In Barind, annual rainfall is very minimal compared to other parts of the country. Rainfed agriculture has been shifted to irrigated agriculture due to drought. Compaction of soil, heavy runoff, low infiltration, inadequate groundwater recharge, low organic matter content, and low soil moisture and water holding are the characteristics of the Barind soil. Drought and land degradation reduce farm agro-biodiversity, water resources, dietary diversity, and food security. Islam and Roberts (2018) reported that several locations in the Barind Tract in Bangladesh have experienced mild, moderate and severe droughts frequently and often extreme drought during the period of 1976–2014. Drought is a natural creeping phenomenon that occurs when extremely low precipitation has been recorded, causing severe hydrological imbalance that badly affects land productivity (UNCCD 2012). Karim and Anwar (2001) reported that the land is affected by different types of droughts in different seasons (Table 12.2).

Land degradation is observed in the high and level Barind Tract areas. It has been mentioned that humans play a dual role in land degradation, either lessening it or speeding it up (Zdruli et al. 2010). The process depends on the scale, location and nature of internal and external factors including soil characteristics and management practices. It depends on climatic factors (temperature, rainfall), air and water resources, and human-induced factors. The effects of land degradation can be minimized through adoption of appropriate land management and farming practices. Nachtergaele et al. (2011) have added a new dimension of the ecosystem in the definition of 'land degradation'. Therefore it needs to be managed in an integrated way, considering the goods and services of the ecosystem and the biophysical and socio-economic value of the land. Human-induced factors (inappropriate land management practices, e.g. deforestation, groundwater withdrawal, indiscriminate use of chemical fertilizers and inappropriate use of crop rotations) are responsible for land degradation. Eventually the natural causes and other climate extremes are responsible for exacerbating land degradation.

Study Objectives

This study was designed to assess and compare drought and land degradation impacts (causes, effects and solutions) between high-drought-prone and low-drought-prone areas. The study also focused on the following objectives:

- To identify land degradation causes
- To identify drought and land degradation consequences
- To elicit solutions to drought and land degradation
- To explore the potentiality of organic practices in reducing drought and land degradation effects on production

The research addressed the following research questions:

- What are the causes leading to land degradation and how?
- Which sites are more vulnerable to land degradation and why?
- What are the devastating effects of land degradation in the study areas?
- What are the existing organic practices available to revitalize degraded land and combat drought?

A drought severity ranking report (Khan and Islam 2013) was used as a basis for selecting two sites to compare land degradation causes and effects – one high-drought-prone site in Tanore Upazila and one low-drought-prone site in Natore Upazila – in order to know the causes of land degradation effects and solutions, and to combat drought and land degradation using natural capital (water, land) and organic farming practices. A total of 300 respondents were selected (150 respondents were selected from each site, considering small, medium and large farm categories) from the high-drought-prone and low-drought-prone areas. A simple semi-structured questionnaire was administered to gauge perceptions about the causes of land degradation, drought and land degradation effects, and the potential to combat drought and land degradation using natural capital and organic farming practices. Eight focus group discussions (FGDs; four from each site: one with young people, one with elderly people, one with females and another with ethnic people) were carried out to better understand their views on the land degradation causes, effects and solutions, and organic practices to combat drought and land degradation at both sites. Six key informant interviews were carried out with a key person from the Department of Agriculture Extension (DAE), teachers and farmers (three from each site) to gain insights for the study. Relevant secondary information was used to support the primary information. After collection of data, it was checked to minimize errors and the data was analyzed using an appropriate statistical package. The study deployed ordinary least square (OLS) to evaluate the efficacy of organic farming practices (crop rotations, zero tillage, crop diversification, use of crop residues, mulching, use of compost, plantations and green manuring) and efficient uses of water (strengthening of bunds, land zoning and mini-ponds) in land degradation and drought management as perceived by the respondents in the study areas. The OLS technique was used to evaluate the efficacy of organic farming practices and efficient use of water in land degradation and drought management, and no heteroscedasticity was found using the Breusch–Pagan/Cook–Weisberg test.

Organic farming practices, drought and land degradation management were denoted with the following equation:

$$L = \alpha_0 + \alpha_1 X_1 + \alpha_2 X_2 + \alpha_3 X_3 + \alpha_4 X_4 + \alpha_5 X_5 + \alpha_6 X_6 + \alpha_7 X_7 + \alpha_8 X_8 + \alpha_9 X_9 + \alpha_{10} X_{10} + \alpha_{11} X_{11} + \mu_1$$

Here,
L = Land degradation and drought management options
X_1 = Strengthening of bunds (dummy)
X_2 = Land zoning (dummy)
X_3 = Mini-ponds(dummy)
X_4 = Crop rotations
X_5 = Zero tillage
X_6 = Crop diversification and mixed cropping
X_7 = Use of crop residues in the field
X_8 = Mulching
X_9 = Use of compost and animal manure
X_{10} = Plantations and agro-forestry
X_{11} = Legumes and green manuring
α_0 = Constant
α_i = Coefficient to be calculated
μ_1 = Error term

Results

Land sustainability is a key issue in Sustainable Development Goal 15 (Life on Land). Several causes and effects of land degradation were identified by the respondents in the study areas. The sustainability matrix showed that a few practices are very effective for drought and land degradation management. All of these causes of, effects of and solutions to land degradation are discussed in several sections and sub-sections in this chapter.

Causes and Effects of Land Degradation

Numerous causes are responsible for land degradation. These causes are both anthropogenic and natural. Drought, low rainfall, use of chemicals and changes in cropping patterns are the proximal causes of land degradation as mentioned by the respondents from high-drought-prone areas (Fig. 12.2). On the other hand, use of chemicals, land fragmentation and changes in cropping patterns are the main land degradation causes in the low-drought-prone areas. Topsoil erosion is an alarming issue in the study areas. Anthropogenic factors are leading topsoil erosion in the study areas.

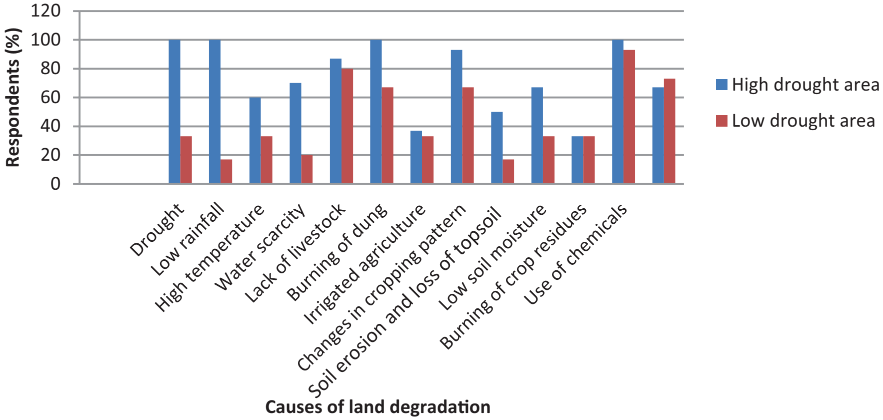

Fig. 12.2 Land user perceptions of the causes of land degradation (Source: Field data, 2018; multiple responses)

Table 12.3 Land and farm ownership types

Ownership type	High-drought-prone areas				Low-drought-prone areas			
	Small	Medium	Large	Total	Small	Medium	Large	Total
Owner	30 (60)	25 (50)	30 (60)	85 (57)	35 (70)	30 (60)	25 (50)	90 (60)
Owner-cum-tenant	20 (40)	25 (50)	20 (40)	65 (43)	15 (30)	20 (40)	25 (50)	60 (40)

Source: Field data, 2018; values in parentheses are percentages

Respondents identified several effects of land degradation including land crises, loss of topsoil, a low-nutritional diet, less income, poverty, soil fertility losses and low production from high-drought-prone areas. The respondents from low-drought-prone areas reported that a low-nutritional diet,[1] less income and poverty are the major effects of land degradation.

Land Ownership Types (Owner Versus Tenant) Cause Land Degradation

The research survey results showed that 57% of respondents have their own land in high-drought-prone areas and 60% in low-drought-prone areas have their own homesteads (Table 12.3). Both tenant and absentee farmers are found in the study areas. More absentee farmers were recorded in the high-drought-prone areas. As mentioned by the DAE staff, only 30% of respondents have their own land and the rest (70%) are absentee farmers. Tenant farms are more affected by land degradation and drought, as stated by the respondents. The tenant farmers lease land from absen-

[1] The respondents from high-drought-prone areas mentioned that they consume two meals a day due to unavailability of food.

tee farmers with terms and conditions. Crop sharing is a common practice and usually a 50% share of the crop is given to the land owners after each harvest. Another option is to pay advance money to the land owner (per unit) for the year or season. There is no guarantee of leasing the land once again after completion of the lease period (season or year). In this context the farmers are not interested in taking care of the land and soil, and considering land sustainability. They know well that the application of cow dung/compost or animal manure/organic matter is a very effective practice for soil and land improvement. This system requires more time and the tenant farmers are not interested in doing it, due to the insecurity of leasing the land for cultivation in the following year.

Climate Variability and Climate Extremes

Climate variability is also responsible for land degradation and drought. It was mentioned by the respondents that the rainfall pattern has changed over time. The length of the rainy season has been shortened and erratic rainfall begins either earlier or later. The environment is becoming drier over time in the high-drought-prone areas. The increased drought frequency reduces crop yields and regeneration activities of plants and animals, as was mentioned by the participants in FGDs. The number of rainy months has been reduced from 6 to 3 months. Following the dry months, the rain starts earlier in March, lasts through April, May and June, and ends in July or August. Thus the low rainfall and erratic rainfall pattern are leading towards land degradation. Similarly the respondents opined that the temperature has been on the rise and has depleted soil moisture, which affects agricultural production. All of these (high temperatures and changes in rainfall patterns, soil moisture and humidity) cause environmental degradation and low agricultural production in high-drought-prone areas.

Drought

Respondents mentioned that drought caused severe land degradation in the high-drought-prone area but there were also other factors. They mentioned that the intensity, frequency and scale of drought have increased over the decades. A few farmers said, “our land is dead and inadequate to provide nutrients for the crops.” They explained that the soil became infertile due to several factors and the crops are not able to grow properly to give good harvests. This was described by the FGD participants. Drought is the leading cause of land degradation and is associated with low yields, a trend towards decreased rainfall and low soil nutrients that are insufficient to support plant growth. It was mentioned by the respondents that drought is the major cause of land degradation, low dietary diversity, low nutrition, ill health and food insecurity. Often, local people from such poor areas migrate to other places to seek income and employment.

Depletion of Soil Organic Matter

As mentioned by a key informant, the soil organic matter is declining over time. In an ideal situation, the organic matter content should be around 5% but it was found to be only 1% in the Barind Tract. Organic matter works as the storehouse of nutrients and provides support to the biotic communities and production. It was mentioned that organic matter is being depleted due to reduced use of organic manure and green manuring practices. Only a few respondents mentioned that they often apply green manure on their farms. In earlier times it was their regular practice on the farms.

Population Pressure

High population is also responsible for land degradation as mentioned by the FGD participants. The increased population and land disturbance activities (soil erosion, infrastructure, excessive tillage) have caused severe land degradation in the high-drought-prone areas. The growing need for more food caused by the excessive population has also impacted on the land degradation process. It was mentioned by the respondents that they have to sacrifice one daily meal (down from three to two), along with diet quality and quantity, and ultimate it leads towards low nutrition, ill health and food insecurity in the high-drought-prone areas.

Gleaning and Burning of Crop Residues

Gleaning[2] and burning of crop residues in the field are also important causes of land degradation. Farmers mentioned that the numbers of earthworms and soil organisms are decreasing at an alarming rate and the land is not able to produce enough crops. Eventually the cost of production is too high in terms of return or gain. Gleaning is done at both study sites but burning of crop residue is mostly done in the high-drought-prone areas (Fig. 12.3). The practice reduces soil organisms by warming up the soil and killing the organisms. It also diminishes the organic matter interacting with the soil on farms.

Lack of Livestock and Dung

It was reported from both study sites that scarcity of livestock and dung is a major cause of land degradation. Respondents said that they do not have enough cows or large livestock and also lack dung to feed the soil. In earlier times, farmers spread

[2] Gleaning is the act of collecting split grain or leftover crops from farmers' fields after they have been harvested.

Fig. 12.3 Burning of crop residues in the field

dung as such practices do improve soil biological properties and support plant growth. Land fragmentation makes the people more vulnerable and impacts livestock and other resources. Eventually farmers become dependent on the market for readily available products (chemical fertilizers) and they are not interested in using dung or green manure. The preparation of compost is a laborious job. Farmers are averse to hard work and are becoming habituated to going to tea stalls to have a cup of tea and pass the time gossiping.

Scarcity of Firewood and Burning of Dung

The availability of firewood and traditional crop residues (as fuel) is sparse now compared to the past. Firewood species and traditional crop species are getting scarce due to drought and land degradation. Eventually most of the people start using cow dung as a fuel (a form of *ghute* or dry cow dung or *doila*) due to lack of firewood or fuel for cooking. It was mentioned that there are acute shortages of cooking fuels (crop residues, firewood and others) in the study locations. People are burning cow dung (which is an excellent fertilizer) to meet the demand for firewood for cooking. Soil and land are being degraded by such practices. Farmers opined that they have no dung to spread on the fields due to its use as a fuel (Figs. 12.4 and 12.5). This action is also accelerating the land degradation process around the country.

Single and Continuous Cropping

Land degradation and low soil fertility are the results of single, similar and continuous cropping. Participants in the FGDs explained the underlying facts of low soil fertility. Farmers are used to planting single crops repeatedly with similar crops, i.e. paddy rice (*Oriza sativa*) for two seasons in a year. They cultivate vegetables or mustard in the break between the two paddy crops. This continuous cropping practice exhausts the soil nutrients especially in the superficial layer. The consequences are that soil nutrients in the deeper layer remain underutilized and the topsoil is overutilized, causing soil fertility imbalances and land degradation. It was also men-

Fig. 12.4 Dung for *doila*

Fig. 12.5 Cooking with *ghute*

tioned that the land is cropped each and every year; there is no resting period for the soil/land to recover. Thus the nutrients are not replenished; therefore the soil cannot provide nutrients for the crops. Low production yields a low income, which creates poverty.

Land Fragmentation and Conversion to Other Uses

Respondents mentioned that land fragmentation is one of the issues of land degradation. They said that a single family gives birth to more families and there is a need for each new family to build new houses and other facilities for them. They explained that their forefathers had fewer mouths to feed. Land has been divided among generations over time. This can be illustrated by the example of Bachhu, who received only two *bigha* of land from his father. His father had received four *bigha* of land from his grandfather and his grandfather had received 8 *bigha* of land from his forefather. Now Bachhu will need to divide his land further between his two sons and a

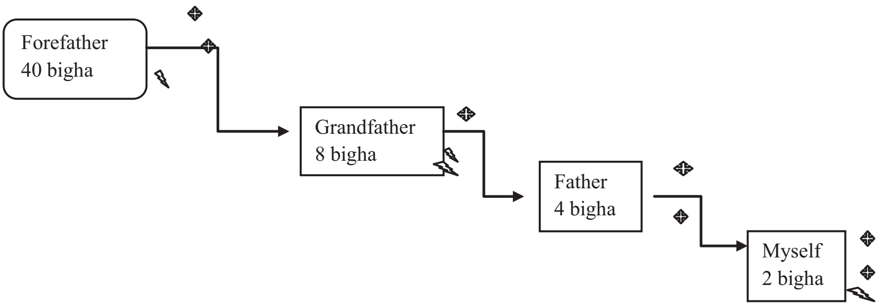

Fig. 12.6 Land fragmentation
Legend: (Male) (Female)

daughter (Fig. 12.6). Again, they will re-assign the agricultural land to other uses (housing, etc).

Faulty Cultivation and Indiscriminate Uses of Chemicals

A participant in an FGD said, "We are habituated to a faulty cultivation process. The plow cart has been replaced by the power tiller and tractor. The use of the rotor tiller makes the soil very susceptible to erosion and the land becomes degraded." Eventually farmers have started using chemical fertilizers instead of organic fertilizers. Again, for crop protection and management, a wide range of chemicals (insecticides, pesticides, herbicides, growth regulators and vitamin supplements) are used by the farmers. Such practices kill beneficial soil organisms and make the soil infertile and gradually the land become degraded. Soil degradation was the prime land degradation concern mentioned by the respondents. One farmer explained the situation of his land in this way: "My land is dead; the soil is dry and now we are crying for food." This means that the soil is losing fertility and crops are not growing well.

Use of Topsoil for Brickfields

Respondents identified the collection of topsoil for brickfields as a serious cause of land degradation (Fig. 12.7). The number of brickfields is increasing with growing demand for infrastructure. There are around 11,100 brickfields in Bangladesh and this problem is causing huge land degradation every year.

Changes in Physical and Biological Properties

It was mentioned by the respondents that several factors are responsible for the changes in the physical and biological properties of the soil. A number of practices reduce the water-holding capacity of the soil by reducing the water infiltration

Fig. 12.7 Collection of topsoil for brick making

Table 12.4 Ordinary least squares and significance level of drought and land degradation management practices

Variable	Coefficient	*t*-value	Significance
Strengthening of bunds	.0505201	1.77	0.078
[a]Land zoning	.9467631	–6.67	[a]0.000
Mini-ponds	.0600598	0.06	0.950
[a]Zero tillage	–.1078469	–1.21	[a]0.005
Crop rotations	.0751319	0.32	0.753
[a]Crop diversification and mixed cropping	.9416129	2.14	[a]0.033
[a]Use of crop residues	–.4551044	–1.96	[a]0.051
[a]Mulching	–.185442	–3.46	[a]0.001
[a]Use of compost and animal manure	.466802	2.79	[a]0.004
[a]Plantations and agro-forestry	.3468439	20.18	[a]0.000
[a]Legumes and green manuring	.436501	2.77	[a]0.005
Constant	2.541278	5.79	0.000
R square: 0.7095			

Source: Author's survey data, 2018
[a]Significant at $P < 0.05$

capacity, soil moisture, and soil organisms, and causing compaction of soil in the high-drought-prone areas. Huge runoff has been observed in high-drought-prone Barind areas due to the nature of the elevated land and the compactness of the soil, in comparison with low-drought-prone areas, during the rainy season.

Combating Drought and Land Degradation

Respondents from high-drought-prone areas reported that drought and land degradation impacts could be managed through efficient use of water (land zoning, water, and rainwater) and organic farming practices (mulching, less tillage, legumes, crop residues, crop rotation, crop diversification and plantations). It was found that land zoning is the only significant measure for water efficiency but zero tillage, mulching, use of compost and animal manure, plantations and green manuring make significant contributions in combating drought and in land degradation management (Table 12.4).

It is possible to manage drought crises and land degradation through organic farming practices, efficient use of water, system integration and restoration of ecosystems.

Zero Tillage

The respondents opined that zero tillage is helpful in managing drought crises and land degradation. Deep tillage and frequent tillage make soil dry by reducing soil moisture and exposing soil to the sunlight during drought. A few farmers are growing grass pea (locally known as *khesari* (*Lathyrus sativus*)), field pea (*Pisum sativum*), garlic (*Allium sativa*) and mustard (*Brassica* spp.), without any tillage in the rice field or low land

Fig. 12.8 Field pea without tillage

Fig. 12.9 Mustard without tillage

(Figs. 12.8 and 12.9). These practices are very much more common in the low-drought-prone areas than in the high-drought-prone areas. Successful cultivation of sweet gourd and mung bean in the T. Aman rice field has been recorded. Zero tillage also reduces plant water requirements. Rice crop residues provide mulching benefits through soil moisture conservation and add organic matter after decomposition. No tillage is required for this crop and it can save tillage costs too. According to the analysis, zero tillage has a significant role in land degradation management (Table 12.4).

Crop Rotations

Tenant farmers do not consider crop types and root depth. Growing the same crops on the same unit of land several times is not a wise decision. Alternative crops can be expected to harvest soil nutrients eventually from a different soil layer. Crop rotations can minimize the impacts of drought and land degradation on agricultural production. A few farmers are growing crops rotationally, whereas most farmers have cultivated only rice for several years continuously. Crop rotation contributes to improving soil fertility, restraining erosion, reducing pest outbreaks and mitigating aridity and land degradations. The analysis showed that there is no significant benefit of crop rotations in drought and land degradation management (Table 12.4)

Mulching

Mulching is a very common practice in low-drought-prone areas. Mulching materials are applied at the base of the crops using easily decomposed materials including dry grasses, straw, compost and crop residues to keep soil moisture in the soil. This provides many benefits as mentioned by the respondents. It conserves soil moisture during drought and hot days; it also reduces the water requirements, reduces soil

Fig. 12.10 Garlic with mulching

Fig. 12.11 Conservation of moisture through mulching

Fig. 12.12 Diversity of crops

temperature and adds fertilizer after decomposition. Mulching practices have effective results in drought and land degradation management (Table 12.4). In the case of potato and garlic cultivation, farmers use straw and water hyacinth for mulching (Figs. 12.10 and 12.11). These practices reduce the irrigation requirement to a greater extent. Less tillage and mulching have also been found to mitigate drought challenges. Organic mulch, when used, increases the soil water-holding capacity, which enhances microbial functions. The practice also reduces the need for tillage to control weeds and conserves soil microorganisms.

Green Manuring

It has been found that legume crops and green manuring practices play important roles in land management (Table 12.4). Green manuring is an age-old practice in the study areas. This is done by growing leguminous crops including *Sesbania grandiflora* (*dhaincha*), sun hemp (*shonpat*) and mung. The growing of *dhaincha* is common practice in Bangladesh. After the first rain in April/May, the farmers scatter *dhaincha* seeds following single tillage and allow them one month for growth. The farmers usually plow the land before flowering of the *dhaincha* and mix it with the

Fig. 12.13 Mixed cropping

soil, then they go for cultivation of other crops. The practice is very helpful in the drought-prone areas. The practices eventually enrich the soil by adding organic matter and increasing the water-holding capacity of the soil.

Crop Diversification and Mixed Cropping

There is a strong relationship between the land and the crop diversification strategy for land degradation management (Table 12.4). Crop diversification is an age-old practice to reduce drought risk (Fig. 12.12). This system contributes to cropping patterns with impacts on the yield and cropping intensity. Growing of a single crop on the whole farm is associated with the risk of crop loss. It is recommended to divide croplands and grow diverse crops to mitigate drought risks. In the past, farmers usually did this to cope with drought. Mixed cropping with intercropping is an effective and successful strategy for crop diversification (Fig. 12.13). It is wise to make intensive use of land as an important survival strategy against drought.

Plantations and Agro-forestry

Respondents expressed the belief that trees can enhance precipitation and reduce drought and land degradation impacts substantially. The analysis also showed a significant correlation with plantation activities, i.e. more plantations correlated with minimum land degradation (Table 12.4). Respondents said they are enacting tree plantation schemes around their homesteads and institutions, on cropland and dykes, and along roadsides and *khari* (lengthy pond-like structures). Farmers are raising seedlings around their homesteads and extending this to the cropland adjacent to their homesteads to reduce drought and land degradation impacts. This provides multiple benefits to the residents in many ways as mentioned by the respondents, such as (i) lowering the temperature; (ii) earning extra income; (iii) increasing trends of rainfall; (iv) conserving soil moisture; (v) maintaining nutritional benefits; (vi) adding fertilizer to the soil after decomposition of leaf litter;

(vii) supplying fuel for cooking; and (viii) providing insurance against crop failure. The system is important in maintaining ecological balance and land improvement.

Efficient Use of Water

Groundwater is not an infinite, constant and endless reserve that can be over-exploited without consequences. Limiting the requirement for groundwater extraction is the most difficult management strategy. Possibly the most commonly argued approach for groundwater demand management in agriculture is the acceptance of 'watersaving knowledge', such as rainwater harvesting, drips and sprinkler irrigation systems. The storage capacity of ponds and canals and the associated *kharies* has been lost. Now the people are re-excavating their traditional ponds, canals and *kharies* to improve water storage facilities during dry spells.

Supplementary Irrigation Using Mini-ponds

Excavation of a mini-pond at the corner of a crop field can contribute as the source of supplementary irrigation during drought. The pond is 12 meters long and 12 meters wide with a 3-meter depth. The pond can harvest runoff water and save the yield of one hectare of land. Some farmers are adopting this adaptation measure but others think that this measure leads towards wastage of cultivating land. Farmers with tiny smallholdings and lease farmers are not interested in wasting land by using mini-ponds. The reasons are that smallholders own only tiny pieces of land and lease farmers have no right to put things on others' land.

Strengthening of Field Bunds for the Retention of Rainwater

Farmers usually preserve water by strengthening field bunds during rains. They usually go to the field to observe leakage of bunds during heavy rains and make new bunds or repair old bunds surrounding their fields. The FGD participants mentioned that a few of them usually go to the field when it is raining or just immediately after rain to check for *dhore* in the *ayle* (a leak in the bund) and repair it or make it strong to prevent seepage (wastage of water) from their fields. Usually these tasks are performed by the men. The ultimate goal is to store water for a longer time and use it for crop growth.

Table 12.5 Management of land according to land categories in high-drought-prone areas

Local classification of land	Cropping pattern	Cultivated crops
Chara	3 crops (rabi–kharif 1 and kharif 2)	Mustard, lentil, wheat, T. Aman rice and tomato
Kandri	3 crops (rabi–kharif 1 and kharif 2)	Mustard, lentil, wheat, fallow and T. Aman rice
Kandur	2 crops (rabi, kharif 1, kharif 2)	Mustard, Boro rice and T. Aman rice

Source: Field work, 2019 (focus group discussions)

Table 12.6 Management of land according to land categories in low-drought-prone areas

Local classification of land	Cropping pattern	Cultivated crops
Danga/ucha	3 crops (rabi–kharif 1 and kharif 2)	Vegetables, maize, mustard, pea, jute and paddy
Leta/beel	3 crops (rabi–kharif 1 and kharif 2)	Paddy, maize, jute and T. Aman rice

Source: Field work, 2019 (focus group discussions)

Land Zoning for Land Management

The results showed that land zoning has a profound effect on practices directed at land degradation management (Table 12.4). There are three types of land found in the high-drought-prone areas, locally known as *chara* (high land), *kandri* (medium land) and *kandur* (low land). Two types – *ucha* (high land) and *nicha* (low land) – are found in low-drought-prone areas. *Chara* is suitable for vegetable farming, *kandri* for other crops and *kandur* for rice farming with minimal irrigation. Respondents reported that they used only low land for rice farming before Barind Multipurpose Development Authority (BMDA) intervention. They produced fewer irrigated rice varieties for farming in earlier times. Nowadays, the farmers are developing crop cultivation plans considering land type to minimize drought and land degradation impacts on agricultural production. Land use planning can play an important role in combating drought and land degradation as mentioned by the FGD participants. The options include stratification of land or zoning of the physical structure of the land. Farmers manage and cultivate suitable crops according to the land types (Tables 12.5 and 12.6).

Sustainability of Drought and Land Degradation Practices

According to the findings of FGDs and key informant interviews, only a few practices including land zoning, zero tillage and mulching are very effective measures for drought and land degradation management in respect of sustainability (Table 12.7).

Table 12.7 Sustainability matrix for drought and land degradation management practices

Management practice	Sustainability of management	Sources
Strengthening of bunds	• Cost effective • Environmentally sound • People are not interested	FGDs and KIIs
Land zoning	• Effective • Environmentally sound • Socially accepted	FGDs and KIIs
Mini-ponds	• Costly • Environmentally sound • Wastage of land	FGDs and KIIs
Crop rotations	• Depends on production • Environmentally sound • People are not aware of it	FGDs and KIIs
Zero tillage	• Low production cost • Environmentally viable • People are interested	FGDs and KIIs
Crop diversification and mixed cropping	• Various types of produce • Environmentally sound • Difficult to manage	FGDs and KIIs
Use of crop residues in the field	• Fuel crises • Good for soil and land • Minimum practices in the field	FGDs and KIIs
Mulching	• Costly materials • Good for soil • People are practicing it	FGDs and KIIs
Use of compost and animal manure	• Cost effective • Good for the environment • Scarcity of manure	FGDs and KIIs
Plantations and agro-forestry	• Economically viable • Environmentally sound • People get diverse benefits	FGDs and KIIs

FGDs focus group discussions, *KIIs* key informant interviews.

Discussion

Land and soil management is an integral part of Sustainable Development Goal 15 (SDG15) focusing on 'life on land'. Several SDGs (2, 3, 6, 11, 13, 14 and 15) are directly linked with the soil and land resources (Tóth 2018). Soil and land are key components of agriculture and influence food security (SDG2 and SGD6), food safety, (SDG3), urban development (SDG11), the land-based blue economy (SDG14) and ecosystem services (SDG15), which all rely on land ecosystems (Tóth 2018). Similarly Keestra et al. (2016) found that there is a linkage of sustainable soil and land management with the other SDGs. Climate variability and several degrees of drought were mentioned by the respondents in the study areas. Islam and Fatiha (2019) reported that droughts and the number of hot days increased in the Barind Tract during the period of 1976–2014. Similar observations were made in another study by Islam and Roberts (2018). The low water-holding capacity of Barind soils is reducing crop yields due to low moisture and inadequacy of nutrients. Stringer and Reed (2007) previously reported research on factors that reduce soil fertility. As we know, topsoil is the farm's capital for agricultural production. Sohrab (2015) reported that fertile soils are damaged by cutting and collection of topsoil for brick-fields. Larney and Angers (2012) argued that poor soil management practices can destroy topsoil through erosion by wind and inappropriate tillage. The respondents also highlighted indiscriminate uses of chemicals in many areas. The Bangladesh Bureau of Statistics (BBS) (2014) reported that the use of chemicals increased from 1695 tons to 40,883 tons between 1995 and 2012. The Bangladesh Agriculture Research Council (BARC) (2012) reported that the second highest (29%) depletion of organic matter was found in the Madhupur Tract (Barind Tract). As a consequence of chemical use, land has become infertile and not able to provide support for plant growth. One study showed that around 3.96 million hectares of fertile land has become strongly to very strongly acidic, with organic matter content of less than 1.7% and a low level of other soil nutrient content (Rahman and Hasan 2003). It has been mentioned that organic matter depletion and soil fertility decline are the main concerns in land degradation (Hossain 2001). Similarly Sohrab (2015) reported that land degradation is continuing in the Barind Tract due to faulty cultivation and other inappropriate natural resource management practices (Sachin 2011, cited in Ceccarelli et al. 2014). Excessive plowing, removal of crop residues and excessive use of chemical fertilizers can degrade soil quality (Lal 2015). Excessive population growth creates huge pressure on land, creating food security issues. Olori (2002) reported that population growth has accelerated the land degradation process in Africa due to huge food requirements. Rural people use crop residues as a fuel and this utilization disturbs soil and land management. Similarly Taddese (2001) reported that there are huge imbalances between livestock and land for crop production. Kundu and Kato (2000) mentioned that land fragmentation reduces net crop land and production due to land degradation and land fragmentation. Soil microbial activity is also affected due to changes in soil biological properties (Larney and Angers 2012). Respondents in the present study in Barind Tract opined that the number of soil organisms (earthworms) and the amount of organic matter have decreased in the study areas. Over the centuries, it has been well recognized that earthworms are useful in restoring land and soil (Darwin 1892). Farmers have paid attention to earthworms and other soil biota and wherever possible use organic manure to improve physical properties of soil.

Organic fertilizers can improve soil by increasing soil porosity, conserving soil microorganisms and enriching soil nutrients. Humus develops gradually and improves soil properties. Organic farming reduces the water requirement during drought and crops can survive with little irrigation. Moebius-Clune et al. (2011) mentioned that organic input into farms can reduce land degradation and improve soil fertility. Around 81% of respondents agreed that organic fertilizers (compost, cow dung, etc.) increase soil fertility leading to higher yields (Islam and Roberts 2018). Lal (2015) reported that recycling of organic byproducts is a very useful practice for soil fertility improvement. Respondents mentioned several practices including use of organic matter (crop residues, compost, animal manure), cultivation of leguminous crops and mulching to improve soil physical and biological properties. The addition and recycling of organic materials (compost, cow dung, and crop residues) are age-old practices for soil improvement and better yields (Montgomery 2012). Similarly Stolze et al. (2000, cited in Niggli et al. 2007) identified huge earthworms, a wide range of populations and biomass found in organically managed soils. The practices mentioned above also reduce soil compaction or erosion, and maintain ecological balance. Gabriel et al. (2013) reported that, compared to conventional farms, organic farms had (i) an overall 12% increase in biodiversity; (ii) more plant diversity; (iii) greater floral diversity; (iv) more earthworms; (v) more insects; (vi) more butterflies; and (vii) increased numbers of some types of birds. Mader et al. (2002) reported that soil microbial activity and abundance of earthworms are greater on organic farms.

Mulching is an effective strategy for land management. Organic mulch not only suppresses weeds, but also stores soil moisture at a high level, which affects germination and weed growth (Edwards et al. 2000). Research findings also suggest that keeping crop residues as mulch in the field can restore soil fertility and reduce land degradation effects (Govaerts et al. 2006, cited in Lal 2015). Manlay et al. (2007) said that the biological aspect of soil management is vitally important to combat soil degradation. Respondents believe it but they are not always able to adopt organic practices due to lack of organic input; it is not available in the market. Respondents opined that it is not possible to improve soil biological properties by using chemical fertilizer. Kimetu et al. (2008) mentioned that no response was found with added urea (N) fertilizers in degraded soil. Respondents knew about the benefits of plantations and agro-forestry for land quality. One study mentioned that plantations and agro-forestry systems can provide benefits in restoring land quality (Kohli et al. 2008, cited in Lal 2015). Similarly Olagunju (2015) suggested integrated approaches including sustainable agricultural practices, awareness programs, and tree planting for restoring land quality. The groundwater table has been lowered in the study areas over time. Effective use of surface water, rainwater, and Mini-ponds is important for efficient use of water. Islam et al. (2018) reported that the groundwater depletion rate was 0.6 meters per year in Tanore during the period of 2005–2014. Others have also reported that the groundwater table is being lowered in this area due to over-withdrawal of groundwater for irrigation (Rahman and Mahbub 2012). Wilhite et al. (2014) reported that drought and land degradation are causing huge damage to livelihoods, property and the environment. Political will is essentially important to combat drought and land degradation. Similarly Low (2013) reported that the land degradation and drought problems remain unfocused issues in the political discussion globally. So organic farming practices, efficient water use policies and political commitment are the key strategies to combat drought and land degradation.

Conclusions and Recommendations

Organic and local practices for soil and land management are essential to restore degraded soil and land. It is not wise to prescribe a few ill-adapted practices for the restoration of degraded land. Use of indigenous species and locally proven technologies have a better chance of success. Researchers have drawn the following conclusions: (i) recurrent drought is severe in the high-drought-prone areas and is characterized by greater severity and more frequent occurrence; (ii) soil and land fertility decline is perceived and identified through low crop production; (iii) farm and homestead agro-biodiversity is low in the high-drought-prone areas; (iv) nutritional status and dietary diversity are low in high-drought-prone areas due to drought and land degradation impacts; (v) the market availability of food is low and the price is high in the high-drought-prone areas; (vi) people in high-drought-prone areas have reduced their meals from three to two per day; (vii) the challenges of drought and land degradation impacts are increasing and food security is at risk in the high-drought-prone areas; and (viii) altogether, this affects farmers' livelihoods and the capacity to feed their families.

More farmers from low-drought-prone areas and few farmers from high-drought-prone areas are paying attention to the potentiality of organic farming practices. Farmers apply their own techniques to improve land quality through intensive practices such as cultivation of legume crops, green manuring, less tillage, relay cropping, intercropping, mixed cropping, bunds, keeping crop residues, living fences and cropland agro-forestry to restore depleted soil and degraded land. Crop rotation is being practiced in the low-drought-prone areas to replenish the soil and land. Ethnic farmers believe that land is a living resource, which provides as life support system through interactions of human and the earth. Respondents opined that the soil in the study areas is being exhausted and they recommended the addition of organic matter (compost, dung) to combat drought and land degradation.

Political will is necessary to ensure land use planning, land distribution and land zoning. Organic farming practices can combat drought and land degradation through adoption of suitable and effective practices of organic farming and efficient water use. It was recommended by the respondents that use of compost, cow dung, crop residues, mulching, mixed cropping, dyke plantations, rainwater, surface water, tree plantations and green manuring practices can reduce drought and land degradation impacts. The land tenure and zoning systems should be user friendly to help farmers combat drought and land degradation impacts.

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Part IV
Concluding Thoughts and Reflections

Livestock are the basis of livelihood for hundreds of millions in Africa, Asia, Europe, Australasia, and the Americas. Livestock affect climate change and are much affected by it. These issues are explored in *Suhubdy, Squires, and Gaur*. The chapter takes a broad overview of the consequences of climate on livestock production (an income source on which millions of people depend) and on human nutrition and health. Undernutrition has serious consequences as manifested in stunting among children. Animal protein (milk, eggs, meat) can help solve problems of under nutrition. Climate change impact on humans is also through the increased incidence of pests and diseases and the spread of disease vectors whose geographic range is expanded as climates change. Examples are the spread of tsetse fly in East Africa and dengue fever carried into new regions by the mosquito.

Land use change is a constant threat to agricultural productivity, especially in response to population pressure, urbanization, infrastructure development, and land degradation. In this chapter, *Gaur and Squires* focus on semiarid regions in India. Changes, especially losses, of agricultural land is a threat to local food security.

Diversification and adaptations in land management practices are occurring everywhere, but the options are more limited in semiarid areas in India. *Pankaj* et al. thoroughly dissect the situation that has occurred and is still ongoing and draw lessons from it. Food security is already at risk.

The upland regions at higher elevations are subject to more rapid climate change. The lives and livelihoods of the local-dwelling people is at risk as seasonal precipitation patterns change and glaciers melt. Similarly the biodiversity of plants and animals must adapt. These aspects (and others) are discussed in detail by *Raghuvanshi, Gaur, and Goyal* using the Ladakh region (a cold arid part in northern India) as the case study.

We (*Squires and Gaur)* as coeditors sought to identify unifying concepts from the chapters presented here. We have case studies from densely populated regions in the tropics, in the desert, and in urban settings. Burgeoning human populations clamor for increasingly scarce resources (water, forage, fodder, nutrients, and arable land) to ensure food security for the near future. In many regions that are too dry for cropping, pastoral peoples maintain large numbers of livestock, and these herds and flocks are destined to increase in response for the growing demand for animal-sourced products.

Climate change is already upon us but is likely to get worse at a time when the global population is projected to reach (or exceed) 9 billion people by 2050. All aspects of food security are potentially affected by climate change, including food access, utilization, and price stability, and these impacts are explained via the various case studies presented.

We earnestly hope that readers will find the chapters stimulating and instructive and that a greater understanding of the multidimensional aspects of both food security and climate variability might be an outcome. If this happens we, as coeditors, will be well pleased as will the writers of the chapter who gave of their time and energy to bring these examples of the complexity of the real world to the readers.

Chapter 13
Reality and Consequence for Livestock Production, Human Nutrition, Health, and Food Security Under the Impact of Climate Change

Suhubdy, Victor R. Squires, and Mahesh K. Gaur

Context and Setting

Climate change is a natural phenomenon that is happening globally and affecting all aspect of livelihoods and possibly the very existence of nature as we know it. One current significant example of the effect of climate change is the disturbance of the production, availability, and distribution of food. Until recently, the total world population was approximately seven billion humans, and it is projected to be over nine billion by 2050. In the developing nations, there are many people suffering from famine, illness, and early death caused by restricted intake of nourishing food. Micronutrient deficiency remains a serious problem in Indonesia with approximately 100 million people, or 40% of the population, suffering from one or more micronutrient deficiencies. In rural areas with poor market access, forests and trees may provide an essential source of nutritious food (Ickowitz et al. 2016). Limiting consumption of food containing animal protein will cause retardation of growth rate and inhibit the development of the brain in humans. Over generations, this will contribute to "lost generations." At the same time, in most developed countries, people have excess production of food grain – a large proportion is used as feed for livestock or is utilized to produce biofuel. One of the agricultural pathways toward sustainable food and nutrition security is through local production of nutritious

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food, an activity in which smallholder farmers play a crucial role. As food consumers, all rural and urban people in developing countries count heavily on the efficiency of their local smallholder farmers and herdsmen to satisfy their food needs.

The Agriculture Sectors' Role in Climate Change

Climate change profoundly affects the conditions under which agricultural activities are conducted. In every region of the world, plants, animals, and ecosystems have adapted to prevailing climatic conditions. As those conditions change, they will all be affected in ways that are difficult to predict precisely. We briefly examine the linkages between climate change, agriculture, and food security (Box 13.1) and discuss the biophysical impacts of climate change on the agriculture sector and how they translate into socioeconomic impacts with consequences for food security and nutrition. We comment on, but do not elaborate, the mechanisms and impact of greenhouse gas emissions and removals from the agriculture sectors and how these contribute to climate change. The implication is that the agriculture sectors need to both adapt to climate change by building resilience and contribute (as a sector) to climate change mitigation.

Box 13.1 Summary of Climate Change Impacts on Agriculture

- Increased frequency and intensity of extreme climate events such as heat waves, droughts, and floods, leading to loss of agricultural infrastructure and livelihoods
- Changes in plant, in livestock and fish diseases, and in pest species
- Decrease in fresh water resources, leading to water scarcity in arable areas
- Sea-level rise and coastal flooding, leading to salinization of land and water, and risks to fisheries and aquaculture
- Water and food hygiene and sanitation problems
- Changes in water flows impacting inland fisheries and aquaculture
- Damage to forestry, livestock, fisheries, and aquaculture
- Acidification of the oceans, with extinction of fish species
- Temperature increase and water scarcity affecting plant and animal physiology and productivity
- Beneficial effects on crop production through carbon dioxide "fertilization"
- Detrimental effects of elevated tropospheric ozone on crop yields

(Sources: Adapted from Tirado et al. (2010) and updated using Porter et al. (2014), HLPE (2012), and IPCC (2014). Impact pathways from climate change to food security FAO (2016)

Food Security and Agricultural Developments

According to the World Food Summit (1996), food security is defined as existing "when all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life." Commonly, the concept of food security is defined as including both physical and economic access to food that meets people's dietary needs as well as their food preferences. Food security is built on three pillars that are (1) *food availability*, sufficient quantities of food available on a consistent basis; (2) *food access*, having sufficient resources to obtain appropriate foods for a nutritious diet; and (3) *food use*, appropriate use based on knowledge of basic nutrition and care, as well as adequate water and sanitation.

Accordingly, agriculture is a main sector that must be responsible for fulfilling the supply component of food security. In this context, the providing of food is not only just referring to availability, accessibility, and usability but also very important to maintain the food quality and continuity. Food quality is related to the capacity of food itself to provide adequate and vital nutritional components such as balancing of protein, energy, vitamins, and minerals. One example of food that could fulfill those requirements stems from livestock products such as meat, milk, and eggs. Intensification of livestock production, especially under Indonesian conditions, is an urgent agenda.

Food security is a complex sustainable development issue linked to human health through malnutrition but also to sustainable economic development, environment, and trade (WHO 2012). More than 85% of Indonesians are living in rural areas where agriculture is the main activity for supporting their livelihoods. It is well known that the agriculture sector is an unstable business due to many affecting conditions. One example of current disturbances is coming from climate change. For example, flooding damages the facilities of irrigation and transportation, soil and water body, crop, forages, and livestock. These conditions are a burden to the rural communities and sometimes make them lose hope and engender frustration.

The agriculture sector contributes 20% globally to GHG emission today and will be reduced 15% by 2020 and less than 10% by 2050. The role of livestock by their emissions of methane (see below) and through the deposition of dung and urine (either directly while grazing or through spread of animal manures from intensive livestock-raising facilities like dairy farms, piggeries, or poultry sheds. Agriculture as a source of GHG is not the main issue, although measures to mitigate the impacts are still required. The pressing problem (main issue) is how to protect agriculture and food production systems from climate change. The magnitude and geographic extent of climate change are quite considerable. Figure 13.1 illustrates the potential change in agricultural output worldwide.

As Fig. 13.1 shows, climate change has a more severe effect on the agriculture sector in developing countries compared to that of developed countries. Meaning that climate change seriously affects the agriculture activity and will have consequences to food security. A more detailed conceptual framework of climate change affecting food security and human nutrition and health is illustrated in Fig. 13.2.

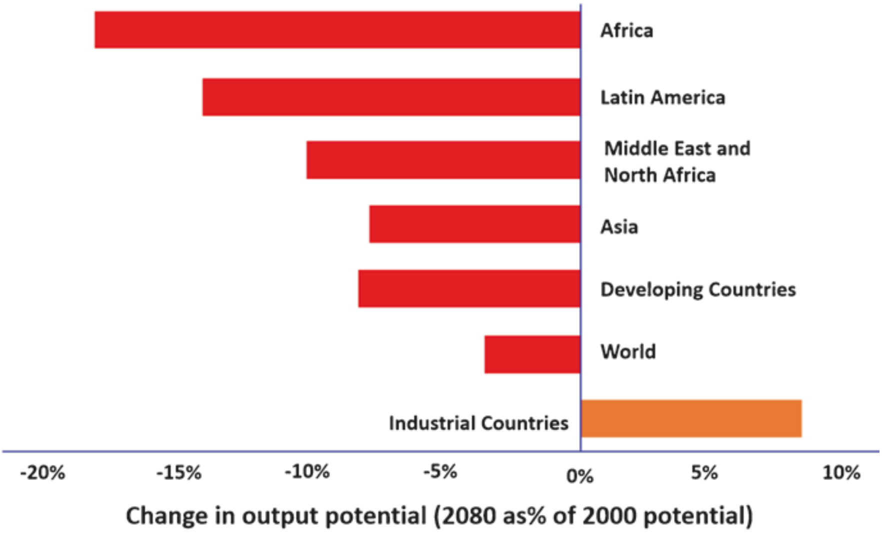

Fig. 13.1 Change in agricultural output potential due to climate change: 2000–2080 (IFAD 2012)

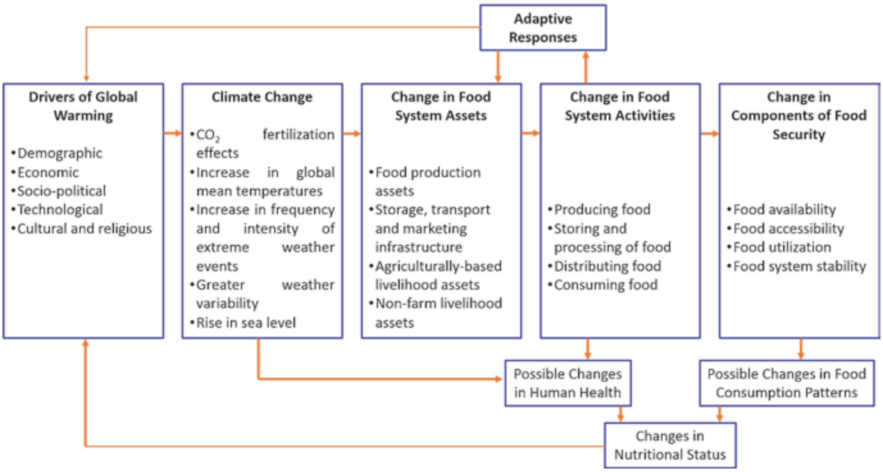

Fig. 13.2 Conceptual framework of impact of climate change in food security (FAO 2007b)

Food System, Agriculture, Human Nutrition, and Health

A food system may be described simply as a process that turns natural and human-made resources and inputs into food (Pinstrup-Andersen 2011). It is essential this concept be understood in relation to relate the agriculture (livestock) production and human nutrition and health (see Figs. 13.3 and 13.4).

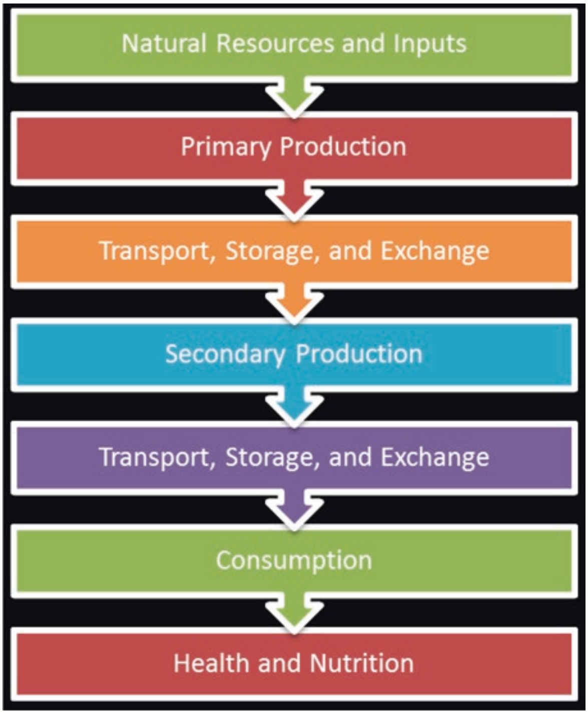

Fig. 13.3 A food system (after Pinstrup-Andersen 2011)

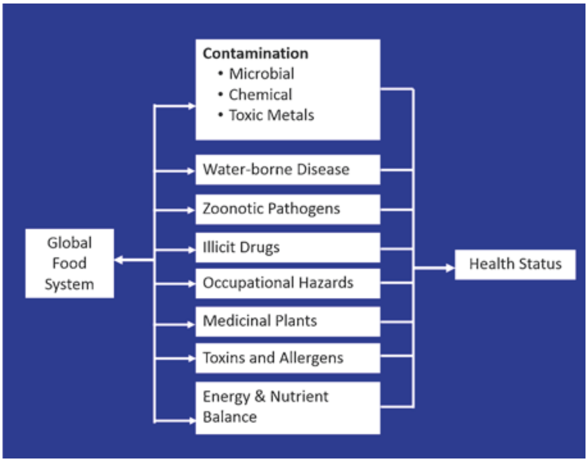

Fig. 13.4 Interaction between food systems and human health (after Pinstrup-Andersen 2011)

As Fig. 13.3 illustrates, agriculture (especially where animal husbandry is at its core) depends upon the availability and balance of natural resources and input interventions to that process. The secondary production (processing, transport, storage, and exchange activities) makes the food available at the time and place desired by consumers. This process must be continued and improved. If the main goal is to improve them, Pinstrup-Andersen (2011) suggested that it is useful to visualize food systems as dynamic behavioral systems that can change in response to change in the behavior of the various decision-makers and agents in the system, such as consumers, producers, market agents, resource owners, nongovernmental organization, and governments.

Food systems operate within biophysical, socioeconomic, political, and demographic environments (Pinstrup-Andersen 2012). In the context of this chapter, more attention is given to the relationship between livestock production, nutrition, and health (Fig. 13.4).

Food systems act as complex social-ecological systems, involving multiple interactions between human and natural components. Nutritional patterns and environment structure are interconnected in a mutual dynamic of changes. The systemic nature of these interactions calls for multidimensional approaches and integrated assessment and simulation tools to guide change. There is an urgent need for a review and conceptual modelling framework that articulates the synergies and trade-offs between dietary diversity, widely recognized as key for healthy diets, and agricultural biodiversity and associated ecosystem functions, crucial resilience factors to climate and global changes is urgently needed. Energy and nutritional deficiencies, infectious diseases, obesity, and chronic diseases may influence food systems by lowering the labor productivity of food systems workers, by reducing the adoption of improved technology and the use of inputs and credit, and by leading to suboptimal use of land, water, and other resources. From the previous explanation, it can be understood that food systems influence critically the human nutrition and health status and, in turn, their productivity.

Climate change affects livestock production in multiple ways, both directly and indirectly (FAO 2016; Steinfeld et al. 2006). The most important impacts are on animal productivity, animal health, and biodiversity, the quality and amount of feed supply, and the carrying capacity of pastures. Increasing variability in rainfall leads to shortages of drinking water, an increased incidence of livestock pests and diseases, and changes in their distribution and transmission (Gray et al. 2009). It also affects the species composition of pastures, pasture yields, and forage quality (Attia-Ismail 2019). For livestock owners, especially in the tropical regions, a major consequence of warming temperatures (as part of climate change) arises from the spread of disease vectors, the survival of larval stages (or eggs and or spores) of parasites, and other pests and diseases. The tsetse fly (*Trypanosoma brucei*) in Africa is an example, and its geographic range has expanded as climatic conditions become more favorable (Squires 2019a). But cattle ticks (*Babesia* spp.), buffalo fly (*Simulium meridionale* and related species), etc. are others. Impacts of climate change on animal health are also documented, especially for vector-borne diseases, with rising temperatures favoring the winter survival of vectors and pathogens. In Europe, global warming is likely to increase sheep tick activity, and the risk of tick-borne diseases, in the autumn and winter months (Gray et al., 2009). Outbreaks of Rift Valley fever in East Africa are associated with increased rainfall and flooding due to El Niño-Southern Oscillation events (Lancelot et al. 2008; Rosenthal and Jessup 2009; Porter et al. 2014).

Higher temperatures cause heat stress in animals, which has a range of negative impacts: reduced feed intake and productivity, lower rates of reproduction, and higher mortality rates. Heat stress also lowers animals' resistance to pathogens, parasites, and vectors' status. Research in India found that a combination of climate-related stresses on sheep – for example, excessive heat and lower nutritional intake – had severe impacts on the animals' biological coping mechanisms (Sejian et al. 2015). The effects of higher temperatures may be reduced in intensive cattle, pig, and poultry production units, through climate control (Thornton et al. 2009), provided that appropriate housing and energy are available. However, projected drier conditions in the extensive rangelands of Southern Africa would increase water scarcity; in Botswana, the costs of pumping water from boreholes increase 23 percent by 2050. In the Near East, declining forage quality, soil erosion, and water scarcity will most likely be exacerbated in the semiarid rangelands (Turral et al. 2011; Mohamed et al. 2019, Emadi 2019). Climate change and climate variability threaten the provision of a range of crucial goods and environmental services, as well as undermine the lifestyles and livelihoods of smallholders across the globe (from the "roof of the world" in the Himalaya-Hindu Kush region (Shang et al. 2019) to the vast areas of Greater Central Asia (including within its boundaries Mongolia, western China, and the five former soviet republics). These nations are (Kazakhstan, Tajikistan, Uzbekistan, Kyrgyzstan, Turkmenistan, and Afghanistan) (Squires and Lu 2018, Squires et al. 2018a) and in the Palaearctic region (Squires et al. 2018) and many other regions in the world.

Climate Change, Food Security, and Livestock Production

Climate change is directly and/or indirectly affecting livestock/animal production. Devendra (2011) distinguished factors which climate change influences the animal production that are heat stress, agroecological zone, water availability, quantity and quality of available feed resources, type of production system, and productivity. Summary of those factors and research and development opportunities is presented in Table 13.1.

According to FAO, the effect of climate change on the production and productivity of the agriculture sectors will translate into mostly negative economic and social impacts, with implications for all dimensions of food security.[1] Climate change can reduce incomes at both the household and national levels. Given the high dependency on agriculture of hundreds of millions of poor and food-insecure rural people, the potential impacts on agricultural incomes – with economy-wide ramifications in low-income countries that are highly dependent on agriculture – are a major concern. By exacerbating poverty, climate change would have severe negative repercus-

[1] The three dimensions of food security (including their dynamics and stability) are A. Availability, production, distribution, and exchange of food; B. Access, affordability, allocation, and preference of food; and C. Utilization, nutritional value, social value, and safety of food.

Table 13.1 Major issues in animal production that will be affected by climate change impacts

Major issues	Potential climate change impacts	Opportunities for R and D
1. Heat stress	– Physiology – Metabolism – Reduced feed intake – Reduced reproduction – Increased mortality – Low productivity – Unsuitable production systems – Reduced multifunctionality	– Adaptation – Feed efficiency – Measures to increase intake – Supplementation
2. Feed resources (forages, crop residues, AIBP, and NCFR)*	– Reduce quantities – Poorer nutrition quality – More fibrous – Decreased palatability – Supplementation	– Use more heat-tolerant plants – Food-feed systems – Use of multipurpose tree legumes – Conservation
3. Land use systems	– Shift to dryland agriculture – Droughts – Water scarcity – Pressure on adaptation	– Heat-tolerant plants and animals – Emphasis on rainfed agriculture – Maximizing feed supply – Increase agronomic practices and use of animal manure to sustain fertility – Conservation practices
4. Animal species and breeds	– Adaptation – Possible reduce in size – Loss of biodiversity – Migratory systems	– Dynamics of nomadic and transhumant systems – Ensuring choice for AEZ – Understanding interactions with the environment – Improving vulnerability and survival of the poor and their animals
5. GHG emissions	– Reduces crop growth and animal productivity – Poor C sequestration – Intensification	– Improved use of grasses, legumes, and agronomic practices – Use of dietary nitrates to reduce CH4
6. Integrated NRM and holistic systems*	– R and D – Advantage of shade in plantations – Increased economic benefits	– Interdisciplinarity – Use of systems perspectives
7. Semiarid and arid AEZs including rangelands	– Reduced feeds – Overstocking – Environmental damage – Improved management – Water use efficiency	– Control of numbers – Landlessness – Use of multipurpose leguminous trees

*AIBP – Agro-Industrial By-products, NCFR – Nonconventional feed resources, NRM – Natural resource management
Source: Devendra (2011)

sions on food security. In a World Bank study, which compared "worst-case" and more optimistic scenarios with a scenario of no climate change (Hallegatte et al. 2016) a scenario with high-impact climate change, rapid population growth and a stagnant economy indicated that an additional 122 million people would be living in extreme poverty by 2030. With the same level of climate change impacts but with universal access to basic services, reduced inequality, and extreme poverty affecting less than 3% of the world's population, the number of additional poor is projected to be just 16 million (Rosenberg and Hallegatte 2015). Under the worst-case scenario, much of the forecast increase in the number of poor occurs in Africa (43 million) and South Asia (62 million). Reduced income in the agricultural sector explains the largest share of increased poverty as a result of climate change. This is because the most severe reductions in food production and increases in food prices occur in Africa and India, which account for a large share of the world's poor. The second most important factor leading to increased poverty is impact on health, followed by the impacts of higher temperatures on labor productivity. Although climate change poses concrete threats to future food security, the likely impacts will differ by region, country, and location and will affect different population groups according to their vulnerability. Future food security trends will also be influenced by overall socioeconomic conditions, which, in turn, have implications for the vulnerability of countries and populations around the world.

When analyzing the possible future impact of climate change on food security, it is important to bear in mind that food and agriculture will be affected by a range of other drivers of change, including growth in population and income (Nardone et al. 2010). Results from IFPRI IMPACT model suggest that, by the year 2050, an additional 40 million more people could be at risk of undernourishment than there would be in the absence of climate change (De Pinto et al. 2016a). Livestock are responsible for 12% of anthropogenic greenhouse gas emissions. Sustainable intensification of livestock production systems might become a key climate mitigation technology. However, livestock production systems vary (Havlik et al. 2014).

Of the sources of specific GHG emissions from agriculture, the most significant contribution at the global level – amounting to 40% in CO_2 equivalent – comes from enteric fermentation[2] in ruminants, which is a major source of methane emissions (Steinfeld et al. 2006). Different species of livestock and various ruminating wildlife have anatomical and other differences that affect methane production (Squires 2019c). Enteric fermentation is the largest source of emissions from agriculture in all regions except Oceania and Eastern and Southeast Asia, with the share fertilizers of total emissions ranging from 58% in Latin America and the Caribbean to 37% in countries in developed regions. As reported by Tubiello and Loujani (2010) in terms of the magnitude of global emissions, this is followed by manure left on pasture (16%), the use of synthetic fertilizers (12%), and rice cultivation (10%).

[2] Enteric fermentation is a digestive process in ruminants, in particular, by which carbohydrates are broken down by microorganisms into simple molecules for absorption into the bloodstream of an animal. Methane, an aggressive greenhouse gas, is a by-product.

Livestock Production and Human Nutrition and Health

It is well known that food produced by livestock/animal such as meat, milk, and egg contains complete and balanced nutrients – energy, essential amino acids, minerals, and vitamins. Consuming much carbohydrate may cause hunger (–) oedema (*kwashiorkor*). Inadequate consumption of Fe can cause anemia. Also, a newborn baby will suffer from calcium (Ca) and phosphorus (P) due to deficiency of Ca and P in mother's milk or limited milk consumption from breast feeding. So, consuming adequate amounts of livestock products (meat, milk, and egg) could overcome the nutritional deficiencies. Also an international issue is that many children under 5 years old in developing countries die because of malnutrition (Fig. 13.5). Malnutrition is unbalance between protein and energy intake. Figure 13.6 illustrates the framework of malnutrition.

Besides providing the better nutrients, livestock production also directly and indirectly influences the human health. For example, disposing manure and urine to the body of water (river or irrigation canals) could contaminate the water and in turn brings waterborne diseases (e.g., malaria, diarrhea). In addition, anthrax is one of the zoonotic diseases that can attack human and animals. Climate change that causes sudden disaster may increase the risk of deteriorating human health. A conceptual

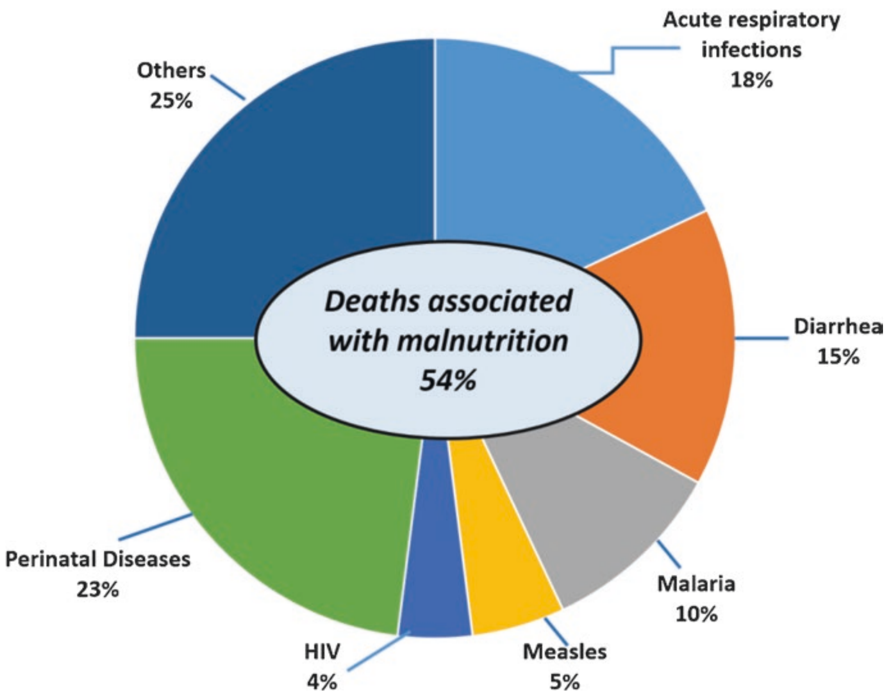

Fig. 13.5 Deaths associated with malnutrition in sub-Saharan Africa (after Watson II and Pinstrup-Andersen 2011)

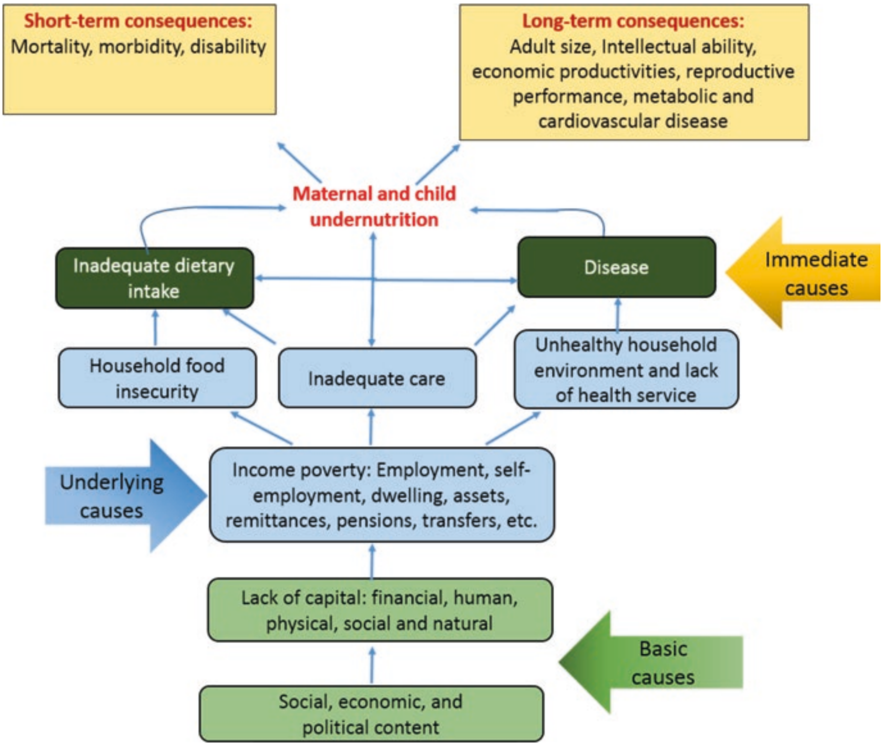

Fig. 13.6 Maternal and child under nutrition framework (Pinstrup-Andersen and Watson II 2011a, b)

framework of the linkage between agriculture (livestock production) and health is depicted in Fig. 13.7. Therefore, appropriate management is also important to be applied to mitigate the disaster from livestock production systems (Gerber et al. 2010). A novel approach to better nutrition based on higher intake of animal protein can be seen in efforts by FAO (and others) to promote use of mini-livestock. These alternative food sources include insects, amphibians, reptiles, and rodents (Squires 2019b).

Summary and Conclusions

Global demand for livestock products is expected to double by 2050, mainly due to improvement in the worldwide standard of living. Meanwhile, climate change is a threat to livestock production because of the impact on quality of feed crop and

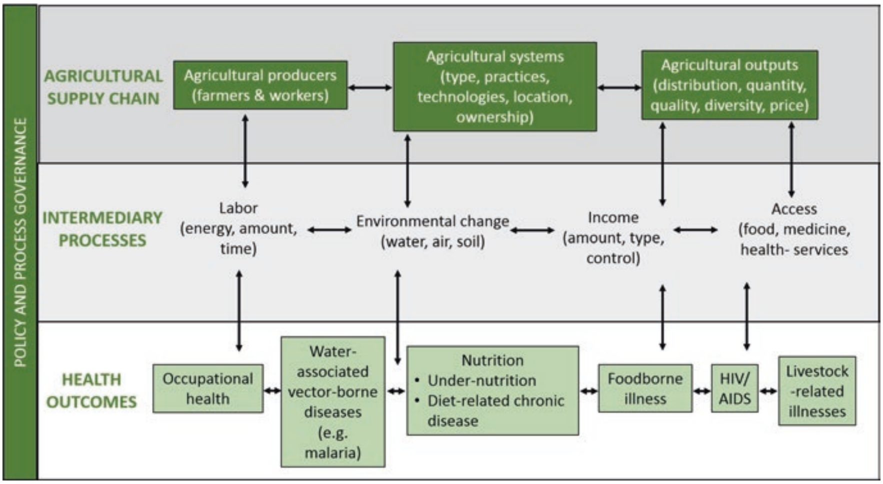

Fig. 13.7 A conceptual framework of the linkage between agriculture (livestock production) and health (after Braun et al. 2011)

forage, water availability, animal and milk production, livestock diseases, animal reproduction, and biodiversity.[3]

Much of agriculture's vulnerability to climate change lies in the fact that its agricultural systems remain largely rainfed and underdeveloped, as the majority of farmers are smallholders with few financial resources, limited access to infrastructure, and disparate access to information. At the same time, these systems are highly reliant on their environment, and farmers are dependent on farming for their livelihoods. Their diversity, context specificity, and the existence of generations of traditional knowledge offer elements of resilience in the face of climate change. Overall, however, the combination of climatic and non-climatic drivers and stressors will exacerbate the vulnerability of agricultural systems to climate change, but the impacts will not be universally felt. Climate change will impact farmers and their agricultural systems in different ways, and adapting to these impacts will need to be context-specific.

The livelihoods of rural communities and their food security are at risk from water-related impacts linked primarily to climate variability. The rural poor, who are the most vulnerable, are likely to be disproportionately affected. Adaptation measures that build upon improved land and water management practices will be fundamental in boosting overall resilience to climate change. And this is not just to maintain food security: the continued integrity of land and water systems is essential for all economic users of water, including livestock owners. Climate change is affecting the food systems and food security. Livestock producers invest significantly in food systems, but intensification of livestock production has led to environmental burdens

[3] Nearly 100 livestock breeds became extinct between 2000 and 2014.17% (1458) of the world's farm animal breeds are at risk of extinction. Genetic erosion is largely due to indiscriminate crossbreeding. Europe, the Caucasus, and North America are the areas with most breeds at risk.

causing groundwater contamination, runoff of contaminated materials, noxious smell, generation of greenhouse gases (particularly methane), and spread of zoonotic diseases. Those burdens are eventually affecting the nutrition and health of human beings. For the future existence of nature and humankind, it is important to consider that efforts for the food production especially livestock production systems must be taken into consideration in the application of adaptable technology, management of mitigation, and those that are environmentally friendly (Fan and Pandya-Lorch 2012).

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Chapter 14
Changes in Agricultural Land Use and Food Security: Challenges for North West, India

Mahesh K. Gaur and Victor R. Squires

Context and Setting

The 2015 FAO food insecurity assessment indicates that the prevalence of undernourishment (PoU) for India is 15.2%, which is greater that the global PoU of 10.8%. India has been addressing food insecurity by providing government subsidies of seed, fertilizer, and other agricultural resources to farmers (Hoda and Gulati 2013). Much of India's rural population cannot achieve food security due to economic and social barriers to get food. India is attempting to address this deficiency through legislation such as the National Food Security Bill, which seeks to reinforce the individual Indian's right to food (Narayanan 2015). India's farms which are typically small are mostly in the hands of resource-poor individuals.

Agriculture contributes 17% to the GDP, with work participation of 47.04% population of the 55% rural population. Agriculture is now considered as marginal employment, and policies that drive people to agriculture are unable to attract youth to this occupation. Condition of food security in India is gloomy and is similar to African countries. Both the supply side and demand side factors have their roles in the present condition of food security and undernourishment in India (Pandey 2015). A significant portion of the economy of Rajasthan is agrarian. The agriculture sector of the state accounts for 22.5% share of agriculture in gross state domestic production (GSDP) which is estimated to 18.39% in 2009–2010. About 80% of the total population resides in rural area and are largely dependent on agriculture as the source of their livelihood. The hot arid region of western Rajasthan

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occupies 61% of the total geographical area and 39.53% population of the state. The burgeoning human and livestock population and increased societal demands for land-based products led to significant expansion and intensification of agriculture by putting even marginal lands under the plow. Excessive exploitation of ground-water and importing of surface water for irrigation underpin this expansion. The per capita availability of land has been on a gradual decline (6.1 ha in 1901 to less than 1 ha in 2011). The situation is further aggravated due to erratic rainfall, rise in temperature, and steady change in climate that influences agricultural production. It is leading to uneconomic and unsustainable overutilization of natural resources thus causing degradation of land and water resources, emergence of irreversible hazards, and damage to microenvironment.

Dry Lands of India

In India, about 69.5% of total net sown area comes under dry and rainfed systems which contribute about 42% total food grain production and 80% of coarse grains/pulse production. India ranks first among the rainfed agricultural countries in terms of both extent and value of produce. The dry lands cover cold arid regions, hot deserts, hilly and undulating uplands, forest areas, plateaus, ravines, and coastal and non-coastal saline areas (Gaur and Squires 2016). They are spread over nearly half of the country and are the home to 43% of the population. Water availability, soil conditions, and the length of the growing season show widespread discrepancies here. Rajasthan, Madhya Pradesh, Maharashtra, Gujarat, Chhattisgarh, Jharkhand, Andhra Pradesh, Karnataka, and Tamil Nadu account for over 80% of the dry lands (Table 14.1). Annual rainfall in the dry lands varies from less than 150 mm to 1600 mm. Soils vary from shallow skeletal soils of the deserts to medium to deep black soils (Gupta and Ojaswi 1996). The prominent dry land regions in India are as follows:

1. Western Himalayas: Cold arid region with rainfall <150 mm
2. Western Rajasthan, Kutch, and northern part of Kathiawar peninsula: Hot arid region with rainfall <300 mm
3. Rajasthan Uplands (Aravallis) and Chambal districts of Madhya Pradesh: Semiarid region with extensive land degradation leading to ravines

Table 14.1 Distribution of dry lands in India (by state)

Dry land area in different regions of India	
States	% of rainfed area
Jammu and Kashmir, Uttaranchal and Himachal Pradesh	60–81
Rajasthan and Gujarat	66–88
Madhya Pradesh, Maharashtra, Andhra Pradesh, Karnataka, Tamil Nadu	76–82
Eastern Uttar Pradesh, Bihar, Jharkhand, Orissa, West Bengal	33–73

4. Central Highlands (including Gujarat plains and Malwa region of Madhya Pradesh): Semiarid region with rainfall of 500–1000 mm
5. Deccan Plateau (including Maharashtra and northern Karnataka): Semiarid region with rainfall of 600–1000 mm
6. Interior Andhra Pradesh (Telangana): Semiarid region with 600–1000 mm rainfall
7. Tamil Nadu Uplands and western Karnataka
8. Subhumid Eastern Plateau (Chhattisgarh): rainfall of 1000–1600 mm
9. Subhumid Eastern Chhota Nagpur Plateau including Jharkhand, western Orissa, and northern Andhra Pradesh: rainfall of 1200–1600 mm

Agricultural Production of Dry Land Region

India has about 108 million hectares of rainfed area which constitutes nearly 75% of the total 143 million hectares of arable land. In such areas, crop production faces much uncertainty as it mainly depends upon intensity and frequency of rainfall. The status of natural resource base is quite variable and is characterized by highly erosive soils, very high evapotranspiration, and low levels of soil organic carbon. Institutionally, there is dominance of small holders having a subsistence orientation focus with weak institutional and credit support. Dry land areas are characterized by low and erratic rainfall and no assured irrigation facilities (Ram and Chauhan 2009). Dry land agriculture is important for the economy as most of the coarse grain crops, pulses, oilseeds, and raw cotton are grown on these lands. The crop production, therefore, in these areas is called rainfed cultivation as there is no facility to give any irrigation, and even protective or lifesaving irrigation is not possible. Figure 14.1 is a chart showing the distribution (by state) of rainfed agriculture. Major rainfed

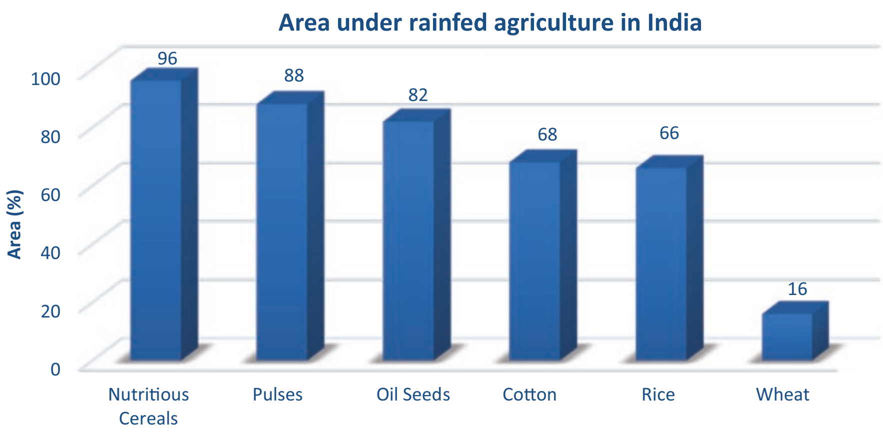

Fig. 14.1 Area under rainfed agriculture in India

crops are millets such as jowar (*Sorghum vulgare*), pearl millet (*Pennisetum typhoides*), and ragi (*Eleusine coracana*), oilseeds like mustard (*Brassica campestris*) and rapeseed (*Brassica napus*), and pulse crops like pigeon pea (*Cajanus cajan*), gram (*Cicer arietinum*), and lentil (*Lens esculentum*).

Almost 80% of maize (*Zea mays*) and jowar (*sorghum*), 90% of Bajra (*pearl millet*), and approximately 95% of pulses and 75% of oilseeds are obtained from dry land agriculture in the country. In addition to these, 70% of cotton (*Gossypium hirsutum*) is produced through dry land agriculture. Dry land areas also contribute significantly to wheat (*Triticum aestivum*) and paddy (*Oryza sativa*) production. Thirty-three percent of wheat and 66% of rice are still rainfed.

So much so that marginal lands in the semiarid regions offer vast potential for fodder production to feed the large number of cattle population which is an integral component of farming practice of this dry lands. These areas offer an opportunity to solve the scarcity of pulses, oilseeds, and cotton. The dry land areas have also tremendous potentiality of increased food grain production. Thus, enhanced agricultural production in the dry lands would boost the agrarian economy and feed the teeming population of the country. Moreover, it would also be helpful in eliminating the problem of hunger and malnutrition prevailing in the below poverty line (BPL) sector of society of the country.

Hot Arid Zone of Western Rajasthan

About 61% of the total area of Indian arid zone is concentrated in 12 western districts of Rajasthan, namely, Barmer, Bikaner, Churu, Ganaganagr, Hanumangarh, Jaisalmer, Jalor, Jhunjhunu, Jodhpur, Nagaur, Pali, and Sikar. These occupy a total geographical area of 208,751 km^2. The region is extended from 24° 37′ 00″ to 30° 10′ 48″ north latitudes and between 69° 29′ 00″ and 76° 05′ 33″ east longitudes (Fig. 14.2). The main characteristics of this hot arid region are low and highly erratic rainfall, high evaporation loss, and extremes of diurnal and seasonal temperatures. The average annual rainfall varies from 456 mm in northeast to less than 100 mm in westernmost part of Jaisalmer district. The coefficient of variability of annual rainfall varies from 40% to 70%. Temperature during long hot summer days rises as high as 50° C, while in cold winter, it falls below −6° C. Mean aridity index is 78%. Probability of occurrence of drought varies from 50 to 60%. Mean moisture index varies from −59.5 in Sikar to −88.9 in Jaisalmer. The length of crop growing period varies from 8 to 15 weeks. The mean maximum expected wind velocity is about 30–40 km h^{-1} but can reach as high as 100 km h^{-1} during severe dust storms. Mean relative humidity during July and August ranges between 75 and 80%, but during winter, it varies from 46 to 56%.

Dominant landforms are the sandy plains with varying degree of hummocks and sand dunes. These are encountered with hills and outcrops (of mainly granite, rhyolite, sandstone, and limestone), saline depressions, and buried channels. Light textured sandy soils cover a major part of this region. Desert soils are mostly sterile

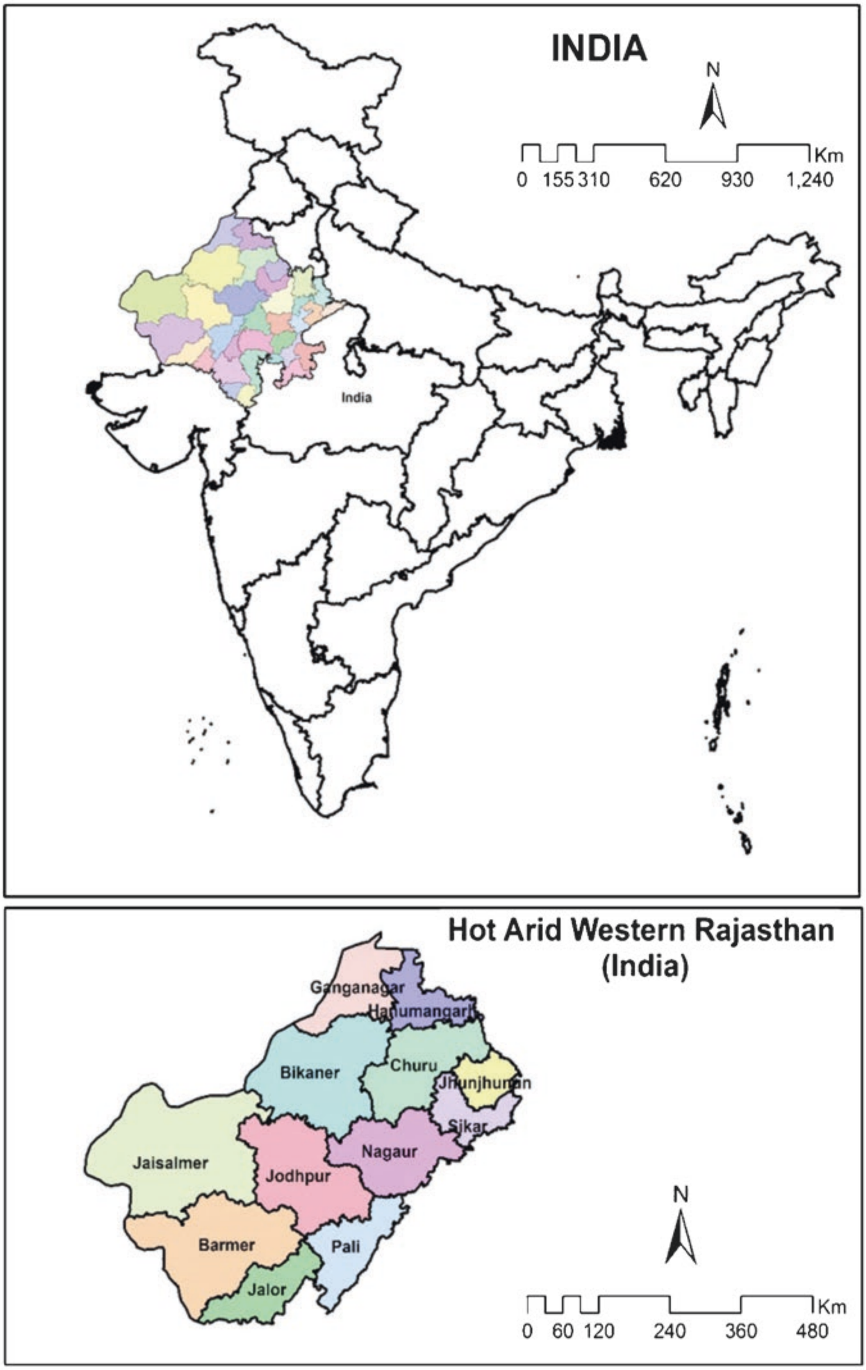

Fig. 14.2 Map of the study area

with a poor fertility status, and poor water holding capacity. They are very low in organic matter, weaker in exchangeable bases, high in pH values, and low in nitrogen and phosphate. The soils have high infiltration rate with low unsaturated hydraulic conductivity (Dhir 1977). Unsaturated hydraulic conductivity refers to a measure of soil's water-retaining ability when soil pore space is not saturated with water.

The vegetation of this region is quite sparse with limited number of xerophytic plants and thorny bushes. The drainage, except the ephemeral *Luni* river system, is mostly internal. Groundwater is deep, scarce, and overexploited. About 45% area has saline to very saline water, and 40% has moderately brackish groundwater. Despite this, the region supports a total domestic livestock population (2012 census) of nearly 30.18 million heads – an increase of 14.63 million heads (94.72%) over the 1956 census figures. The desert region has about 52.3% of the State's livestock. As per 2011 census, the region has 27.12 million human population. The density of human population varies from 17 persons per sq. km. in Jaisalmer to 361 persons per sq. km. in Jhunjhunu district and that of livestock from 83 heads per sq. km. in Jaisalmer to 274 heads per sq. km. in Sikar (Gaur et al. 2018a, b).

Global Nutritional Food Security

The global food security challenge is straightforward: by 2050, the world must feed 9 billion people. The demand for food will be 60% greater than it is today. The United Nations has set ending hunger, achieving food security and improved nutrition, and promoting sustainable agriculture as the second of its 17 Sustainable Development Goals (SDGs) for the year 2030. To achieve these objectives requires addressing a host of issues, from gender parity and aging demographics to skills development and global warming (Feng et al. 2018). Agriculture sectors have to become more productive by adopting efficient business models and forging public-private partnerships. And they need to become sustainable by addressing greenhouse gas emissions, water use, and waste. The risks include malnutrition, hunger, and even armed conflict (IFAD 2016; IUCN 2017).

Failure to increase investment in protecting and restoring dry lands – soils in particular – could put future food supplies at risk and hamper efforts to mitigate and adapt to climate change (IUCN 2017). Dry lands, which include habitats such as savannas, mist forests, and oases, cover 41% of all land on Earth. They are home to one third of the world's population and store 36% of global terrestrial carbon. They also sustain 44% of the world's cultivated systems and 50% of the world's livestock (Squires et al. 2019). Most of dry land biodiversity is found in the soil, which determines the overall fertility and productivity of the land. Land degradation in dry lands – known as desertification – could result in a 12% fall in global food production in the next 25 years (Squires and Ariapour 2018). It could also contribute to global carbon dioxide emissions, with about 60% of carbon in soils lost through land degradation. It is estimated that between 25 and 35% of dry lands are being degraded, which undermines their productivity. Over

250 million people are directly affected, and a further 1 billion in over 100 countries are at risk (IUCN 2017).

Therefore, dry lands are absolutely key to global food security for the whole planet. Environment friendly and water-efficient agriculture for smallholders are keys to reducing poverty, boosting smallholder adaptation to climate change, and rehabilitating degraded lands. We look to empower more rural farmers to sustainably manage their land, so that while they feed their families for generations to come, they can also get out of poverty (IFAD 2016).

The majority of the arid dry lands are partly or severely degraded, meaning that biological and agricultural productivity are significantly impaired. A wide range of restoration technologies have been successfully applied, including planting of soil improving trees or shrubs, application of manure, and establishment of dams or terraces for water harvesting (Heshmati and Squires 2013). Even a fraction of such restored dry lands can provide additional billions of tons of valuable food, fodder, and biomass in a highly sustainable way while restoring soil quality and sequestering carbon dioxide back into biomass and soil. Consequently a decisive dry land restoration program will significantly enhance food security and mitigate global warming (http://www.sustainabilitylabs.org).

Dry land agriculture plays an important role in the progress of agriculture in the Indian economy. In India, 68% of total net sown area (136.8 Mha) is from dry lands spread over 177 districts. Dry land crops account for 48% area under food crops and 68% area under nonfood crops. Nearly 50% of the total rural work force and 60% of livestock in the country are concentrated in the dry districts (DHAN Foundation 2006). Development strategies have shifted resources away from dry land to irrigated production and from rural to urban areas. Since dry land farmers are poorer and politically less influential, the effects of adverse macroeconomic policies fall disproportionately on them in spite of the fact that they are often the primary producers of food crops. Despite concerted efforts made in the past to improve the productivity by transferring improved technologies, gains in terms of higher yield and income have not been spectacular due to associated risks like aberrant weather, land degradation, and poor socioeconomic base of the farmers. Although a major constraint to dry land agriculture is deficient water, hazards such as insects, diseases, high winds, and intensive rain/hail can destroy crops in a matter of minutes or days. Farmers in dry land regions are often resource-poor, and these regions are usually of low priority when national resources are allocated. There are three constraints in dry land agriculture—physical, technological, institutional – infrastructural and socioeconomic (Rajakumar et al. 2007).

Nutritional Food Security in Western Rajasthan

Western Rajasthan's top agriculture commodity is pearl millet, followed by cereal grains of wheat and rice. Vegetables and potatoes are also significant agricultural products. Sugarcane is mostly processed into commercial products and exported.

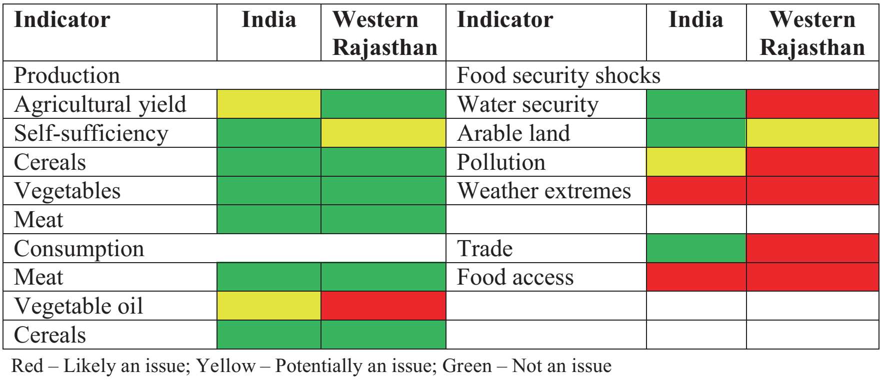

Fig. 14.3 Food security status in India and western Rajasthan
Note: adapted from Michael S. Finnin (2016) Food Security in India, China, and the World, Institute for Defense Analyses, Virginia

Production in cereals has been steadily growing, with wheat production increasing at an annual rate of 4.2% from 1961 to 2016 (Ittyerah 2013; Khadka 2018). As expected, meat production in India is low compared with other emerging nations. India had produced approximately 6 million tons of total meat in 2013 (Fig. 14.3) compared with China's 70 million tons. Meat production is growing at a rate of 1% per year in India; in China, it is growing at nearly 7% per year (http://www.foodsecurityportal.org/india).

Cropping Pattern

In spite of the hot desertic conditions, western Rajasthan occupies 70.3% of the total cropped area under pearl millet crop in Rajasthan state, cluster bean 93.7%, *Vigna aconitifolia* (moth) 99.9%, mung bean (*Vigna radiata*) 81.1%, sesame 535.%, groundnut 78.8%, mustard 38.7%, cumin 96.7%, and Psyllium husk (*Plantago ovata*) 92.9% as per agricultural statistics 2015–2016 (Table 14.2). Pearl millet, cluster bean, *Vigna aconitifolia* (moth), mung bean (*Vigna radiata*), and sesame are most important rainfed *kharif* season crops produced throughout the region covering 11.9%, 13.98%, 3.17%, 3.98%, and 1.07% of the total cropped area in western Rajasthan.

Sorghum and cowpea are less significant crops. Sorghum (1.87%) is mainly produced in Pali, Nagaur, and Jodhpur districts and cowpea (0.80%) in Sikar, Jhunjhunu, and Nagaur districts. Wheat, mustard, gram, groundnut, and cotton are important irrigated crops constituting 7.19%, 5.36%, 4.89%, 1.51%, and 2.78%, respectively. Others are barley (0.83%), cumin (1.45%), Psyllium husk (1.65%), and paddy rice (0.25%). Cumin and Psyllium husk (isabgol) are mainly taken in Barmer, Jalor, Nagaur, and Jaisalmer region; barley in Sikar, Ganganagar, and Hanumangarh districts, and paddy rice absolutely in Ganganagar and

Table 14.2 Area (%) of important crops in western Rajasthan (2015–2016)

District	Pearl millet	*Vigna radiata* (mung bean)	*Vigna aconitifolia* (Moth)	Sesame	Groundnut	Cotton	Cluster bean	Wheat	Gram	Mustard	Cumin	Psyllium Husk
Barmer	42.2	3.5	11.8	0.4	0.2	0.0	25.1	0.8	N	0.7	7.2	5.8
Bikaner	4.1	0.2	12.3	0.3	8.1	0.0	50.9	5.6	11.8	3.2	0.4	0.3
Churu	21.1	6.0	24.0	0.3	3.4	0.0	28.6	2.4	8.2	3.2	0.1	0.3
Ganganagar	0.1	2.4	N	0.2	0.1	4.1	43.0	20.2	5.0	17.7	N	N
Hanumangarh	2.3	1.4	2.3	0.1	0.6	11.5	41.0	18.8	6.8	9.7	N	N
Jaisalmer	9.0	1.7	0.1	0.5	1.7	0.0	60.0	1.2	12.8	4.5	3.8	3.5
Jalor	31.7	11.2	1.2	2.7	1.6	N	10.0	4.5	0.2	9.5	10.4	6.6
Jhunjhunu	34.7	4.3	0.1	N	0.5	0.3	18.2	13.9	7.9	11.4	N	N
Jodhpur	23.5	10.1	7.0	2.3	6.6	2.5	15.9	4.0	0.3	6.9	8.6	1.4
Nagaur	24.0	25.9	8.2	0.8	1.0	4.0	13.1	4.1	0.5	4.0	3.4	2.7
Pali	6.5	24.1	0.1	12.7	0.1	1.7	7.2	8.4	3.4	8.2	2.8	0.3
Sikar	37.7	3.4	0.3	0.1	3.0	0.0	17.9	12.8	4.3	6.8	0.0	0.1
Total (ha)	2,867,156	1,106,396	1,087,174	196,123	410,609	322,123	4,488,876	1,105,172	762,771	980,452	494,285	282,900
% to TCA	70.3	81.1	99.9	53.5	78.8	72.0	93.7	35.5	81.0	38.7	96.7	92.9
State %	11.90	3.98	3.17	1.07	1.52	1.31	13.98	9.07	2.75	7.39	1.49	0.89

Source: Statistical Abstracts, Government of Rajasthan

Hanumangarh districts. Castor (0.64%) and Taramira (0.13%) are mainly taken under conserved moisture. Castor is mainly produced in Jalor, Jodhpur, and Barmer districts. Similarly gram is planted both under irrigation and utilizing conserved moisture. Producing areas of other crops are fenugreek (Sikar, Bikaner, Nagaur, Jhunjhunu), onion (Jodhpur, Pali, Sikar, Jhunjhunu), henna (Pali), and red chillies (Jodhpur). Besides, coriander, garlic, fennel, linseed, sugarcane, potato, and sweet potato are also taken in small and fragmented pockets. The area under fodder and vegetable and fruit crops is extremely low, reflecting the demand in the region.

Crop Production

Small and marginal holdings agriculture is important for raising agriculture growth food security and to improve the economy in the world's dry lands (Squires and Gaur, this volume). These holdings contribute to 80% of dry land agriculture. And, frankly, the future of sustainable agriculture growth and food security of the dry lands depends on the performance of these small and marginal farmers. Out of the total crop production in the region, i.e., 14.36 million tonnes, 39.19% is contributed by cereals, 12.27% by pulses, 28.22% by oilseed, and 32.59% by other commercial and cash crops as per agricultural statistics 2015–2016. District wise production of above group of crops is given in Table 14.3. Bikaner, Churu, and Nagaur have highest production of pulse crops, while Ganaganagar, Jodhpur, Hanumangarh, Bikaner, and Nagaur have dominancy over oilseed production. Hyper arid Jaisalmer district contribute only 5.66% of the total crop production in arid Rajasthan. The production of rice during the year was 133.1 metric tonnes (MT), pearl millet 1442.9 MT, sorghum122.14 MT, Kharif pulses (including mung bean (*Vigna radiata*) and *Vigna aconitifolia* (Moth)) 801.34 MT, sesame 53.95 MT, groundnut 920.19 MT, cotton 149.81 MT, wheat 3576.287 MT, barley 356.12 MT, gram 656.10 MT, mustard 1231.38 MT, and Psyllium husk, respectively. Nagaur district tops in pearl millet, mung bean (*Vigna radiata*), and Psyllium husk production; Pali in sorghum, sesame, and henna; Churu in *Vigna aconitifolia* (moth), Sikar in cowpea and fenugreek; Bikaner in groundnut, cluster bean, and gram; Ganganagar and Hanumangarh in wheat, mustard, barley, and cotton production; Jalor in castor and cumin; and Jodhpur in chillies production. Barmer district though have significant area under pearl millet, cumin, Psyllium husk, and castor, but production remains low due to extremely arid conditions.

The production of rainfed crops is entirely dependent on the availability of moisture and other climatic conditions and as such causes the production use to fluctuate from year to year. Therefore, during moderate and severe drought years, the production goes down at to a very low level despite the increased area cropped.

Table 14.3 Production (%) of cereals, pulses, oilseed, and other crops in western Rajasthan (2015–2016)

District	Cereals	Pulses	Total food grains	Oilseeds	Others	Total
Barmer	25.55 (3.93)	0.20 (0.07)	25.76 (2.72)	22.28 (3.27)	51.96 (6.61)	221017 100.00 (4.14)
Bikaner	16.89 (8.54)	32.78 (36.38)	49.67 (17.26)	31.83 (15.36)	18.50 (7.73)	726443 100.00 (13.62)
Churu	22.17 (3.07)	25.42 (7.73)	47.59 (4.53)	45.50 (6.01)	6.91 (0.79)	198987 100 (3.73)
Ganganagar	23.55 (22.56)	4.79 (10.07)	28.34 (18.65)	17.41 (15.91)	54.25 (42.93)	1376024 100.00 (25.79)
Hanumangarh	37.38 (20.24)	5.40 (6.42)	42.78 (15.91)	16.85 (8.70)	40.37 (18.06)	777684 100.00 (14.58)
Jaisalmer	6.27 (1.32)	46.73 (21.57)	53.01 (7.66)	23.00 (4.61)	23.99 (4.17)	302105 100.00 (5.66)
Jalor	22.22 (4.59)	0.18 (0.08)	22.40 (3.18)	54.15 (10.68)	23.45 (4.00)	296874 100.00 (5.56)
Jhunjhunu	45.37 (7.29)	19.41 (6.84)	64.78 (7.15)	30.10 (4.61)	5.13 (0.68)	230850 100.00 (4.33)
Jodhpur	22.16 (8.04)	3.51 (2.79)	25.67 (6.40)	51.73 (17.91)	22.59 (6.77)	521291 100.00 (9.77)
Nagaur	30.83 (5.83)	4.23 (1.76)	35.06 (4.56)	26.59 (4.80)	38.35 (6.00)	271786 100.00 (5.09)
Pali	43.40 (4.46)	6.78 (1.53)	50.18 (3.54)	37.46 (3.67)	12.35 (1.05)	147650 100.00 (2.77)
Sikar	54.96 (10.12)	11.78 (4.76)	66.73 (8.44)	25.32 (4.45)	7.94 (4.45)	264417 100.00 (4.96)
Total	1436469 (26.52)	654580 (12.27)	2091049 (39.19)	1505526 (28.22)	1738553 (32.59)	5335128 100.00

Figures in bracket show percentage to total area under a crop
Source: Statistical Abstracts, Government of Rajasthan

Operational Land Holdings in Arid Rajasthan

With land holding getting smaller, the share of small and marginal holdings in the country has risen to 86.21% of total operational holding in 2015–2016. As per the agricultural census of 2015–2016, the total number of operational land holdings in the Rajasthan state was 76.55 lakhs. (A lakh is a unit in the Indian numbering system equal to one hundred thousand (100,000). There were 40.12% marginal, 21.90% small, 18.50% semi-medium, 14.79% medium, and 4.69% large holdings. An increase has been observed in the number of marginal, small, semi-medium, and medium land holdings, whereas a decrease is in the number of large land holding during the 2015–2016 in comparison with 2010–2011 census. This indicates a tremendous increase in the number of small holdings in the western Rajasthan, due to fragmentation of land due to divisions of joint families, while that of medium and large holdings have gone down.

Figure 14.4 (a & b) clearly indicates that the size of operational holdings has thus been declining year by year leading to increase in the number of marginal and small holdings and fall in the number of medium and large holdings. All this has resulted from continuous subdivision and fragmentation of land holdings in the dry lands of western Rajasthan. Figure 14.5 and Table 14.4 depict district-wise distribution of average size of operational holdings and variation in all social groups in western Rajasthan.

The average size of holdings had become progressively smaller because of land fragmentation brought on by inheritance laws and other factors (see text below). It is evident from Fig. 14.5 that Ganganagar district has experienced the greatest decrease (103.45%) in operational land holding due to the canal introduction. It is followed by Pali district where 85.70% decline has occurred due to industrialization. Jaisalmer (41.04%), Churu (43.01%), and Barmer (44.18%) districts have experienced least decline in operational land holding as agriculture is totally dependent on monsoon rain, and surface water sources are almost unavailable. Having a large holding does not mean much in rainfed areas. However, this pattern of holdings would reflect on agricultural practices. Large land holdings are a reflection of the harsh environmental conditions (Gaur 2016; Gaur et al. 2020).

The important causes of growing subdivision and fragmentation of agricultural holding in the region are:

- Fall of Joint Family System: Under the system of joint family, there was no need to subdivide the size of agricultural holding. But under the impact of growing industrialization and urbanization, the joint family system is breaking up rapidly leading to a subdivision of agricultural holdings.
- Increasing Pressure of Population: With the rapid growth of population *in desert region*, the pressure of population on land is increasing. In view of a near absence of the growth of alternative occupations, people started to put much pressure on agriculture leading to continuous subdivision of land.
- Laws of Inheritance: In India, as a whole, the laws of inheritance have made provision for equal share of the ancestral property among the offspring. Due to

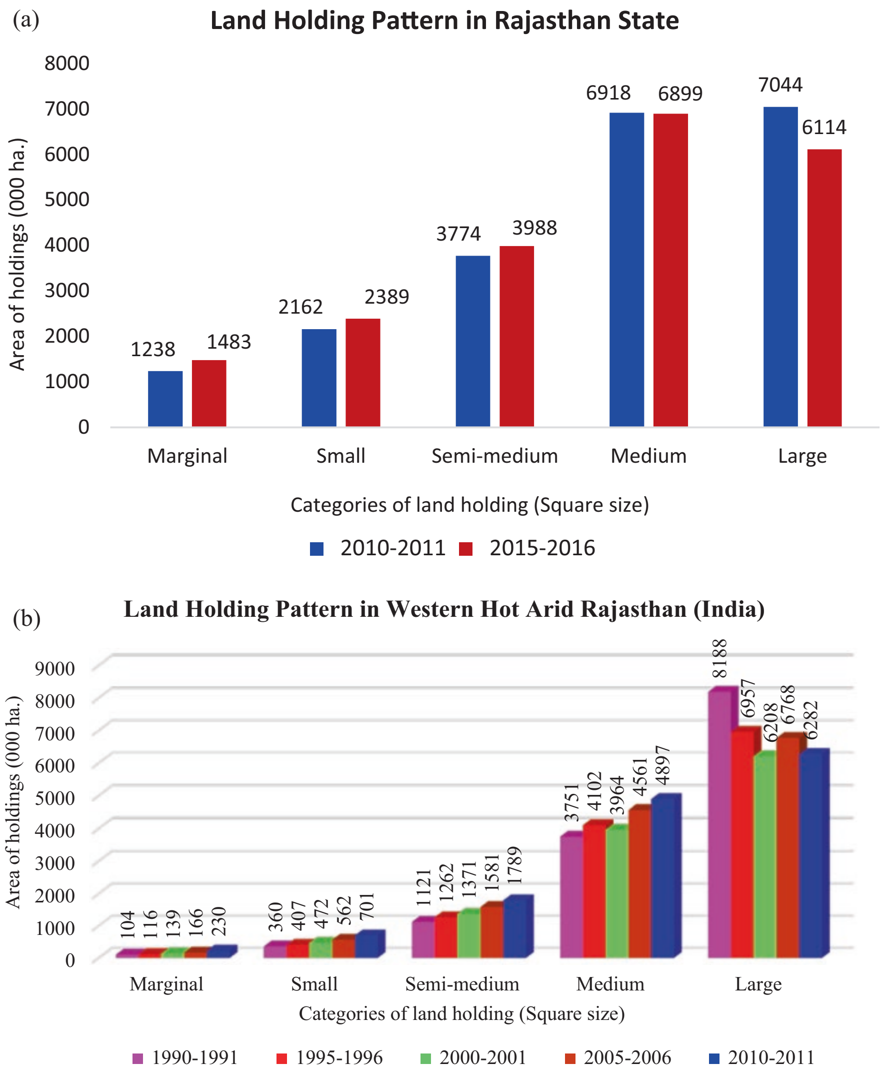

Fig. 14.4 (**a**) Land holding pattern in Rajasthan State (India) (**b**) Land holding pattern in western hot arid Rajasthan (India)

the application of this law, there is a continuous split in the size of farms with every new generation.

- Decline of Rural Industries and Artisanship: Due to destruction of village handicrafts and industries, artisans were forced to discard their family occupations and started to depend on agriculture. This has added another aspect to the problem.
- Rural Indebtedness: High degree of rural indebtedness is another cause contributing to this problem of subdivision of land holding. Due to frequent drought and

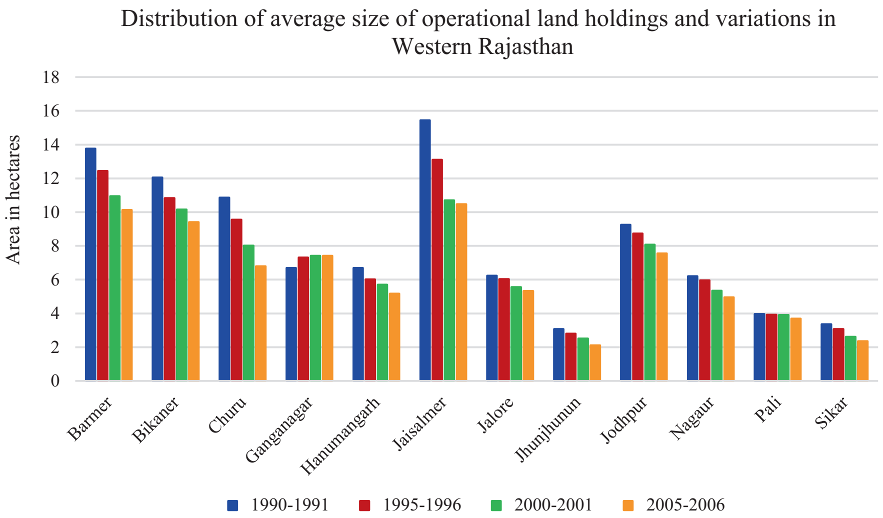

Fig. 14.5 Distribution of average size of operational land holdings and variation in western Rajasthan (India) (area in hectares)

Table 14.4 Distribution of average size of operational land holdings and variation in western Rajasthan (India) (area in hectares)

District	1990–1991	1995–1996	2000–2001	2005–2006	2010–2011	% variation in 2010–2011 over 1990–1991
Barmer	13.77	12.44	10.95	10.13	7.98	-44.18
Bikaner	12.05	10.83	10.16	9.41	8.75	-60.56
Churu	10.86	9.56	8.02	6.8	5.85	-43.01
Ganganagar	6.7	7.32	7.42	7.42	7.38	-103.45
Hanumangarh		6.02	5.7	5.18	4.93	-66.88
Jaisalmer	15.44	13.1	10.7	10.47	8.72	-41.04
Jalor	6.24	6.03	5.56	5.33	4.94	-72.93
Jhunjhunu	3.07	2.8	2.51	2.12	1.77	-54.58
Jodhpur	9.25	8.73	8.08	7.56	7.1	-67.51
Nagaur	6.00	5.96	5.35	4.96	4.38	-64.32
Pali	3.97	3.93	3.91	3.7	3.56	-85.70
Sikar	3.37	3.08	2.62	2.36	1.96	-54.79

Source: Statistical Abstracts, Government of Rajasthan

famines, crop failure is quite common. Loans taken from banks and village moneylenders could not be returned on time, and borrowers are declared defaulters by the agencies. In such a situation, these cultivators are forced to sell their land, and in only a few cases does this allow land consolidation.

Due to subdivision of holding a good amount of land (about 3–5%) is being wasted for drawing boundaries and planting hedges between huge numbers of tiny plots. Furthermore, due to subdivision, the plots become so small that it is quite uneconomic to cultivate such land. Fragmentation of agricultural holding creates difficulties to the farmers to manage the agricultural operation smoothly. Also, smaller size of holdings cannot provide full-time job to all the members of farmer's family. Thus, in the absence of alternative occupations, chronic (often hidden) unemployment started to occur in the rural areas.

Changes in Agricultural Land Use, Cropping Pattern, and Crop Production

The human population in the region has increased from 7.64 million in 1961 to 27.12 million in 2011 and that of livestock population from 13.72 million in 1961 to 30.18 million in 2012. This burgeoning pressure and societal demands on one hand and division of holdings on the other led to expansion and intensification of agriculture through reduction in fallowing practices, bringing more land under cultivation from the "culturable waste" category (often with supplementary irrigation). Expansion of cultivated area is mainly taken place in Bikaner, Jaisalmer, Churu, and Barmer districts, whereas intensification of agriculture taken place in Sikar, Jhunjhunu, Ganganagar, and Hanumangarh districts. During the period from 1960–1961 to 2007–2008 (Malhotra et al. 1983 and Anon 2010), the net sown area has increased by 33.64%, total cropped area by 60.44%, and double-cropped area by 20 times. On the other hand, culturable waste lands have declined by 21.81%, other fallow lands by 36.13%, and current fallow by 17.15%, respectively. The net irrigated area has increased by 366.92% (from 0.61 to 2.85 Mha).

The development of irrigation and introduction of the sprinkler system brought significant change in cropping pattern particularly in canal irrigated area. Cumin, Psyllium husk, fenugreek, fennel, and castor were introduced as new crops after the 1980s. Similarly large-scale cultivation of gram and *Eruca sativa* (taramira) on the conserved moisture was taken up. The mixed cropping practice like pearl millet +*Vigna aconitifolia* (moth) + cluster bean or pearl millet + mung bean (*Vigna radiata*) + cluster bean is almost withdrawn. The changes in area and production of important crops from 1970–1971 to 2008–2009 are given in Table 14.5. The acreage of rice, wheat, groundnut, mustard, and cotton has increased by 153.5, 117.3, 935.0, 1988.6, and 289.7 per cent, respectively. Sorghum, barley, and gram have registered marginal increase. The acreage of sesame has declined by 5.3%. Similarly the production of wheat, barley, groundnut, mustard, and cotton has increased manifolds, while the production of sesame, sorghum, and rice has declined.

The acreage of pearl millet though slightly declined over the years to give way for other crops, but its production has increased by 26.4% (Table 14.5). As such the productivity of almost all the crops has increased by adoption of new farming technologies and high-yielding varieties although the acreage of a few rainfed crops has declined.

Table 14.5 Trend in area and production of principal crops in western Rajasthan

Crop	Area (000 ha)			Production (000 tonnes)		
	1970–1971	2015–2016	Change (%)	1970–1971	2015–2016	Change (%)
Rice	13	46	253.85	23	133	428.26
Sorghum	229	226	-1.31	93	122	31.18
Pearl millet	4179	2806	-32.85	1966	1442	-26.65
Wheat	405	1105	172.84	525	3576	581.14
Barley	112	113	0.89	127	356	180.31
Kharif pulses	1614	2250	39.41	432	801	85.42
Gram	679	763	12.37	263	656	49.77
Groundnut	20	411	1955.00	4	920	22900.00
Sesame	262	196	-25.19	69	54	-21.74
Mustard	35	981	2702.86	42	1231	2830.95
Cotton	97	322	231.96	133	150	12.78

Source: Agricultural Statistics, Rajasthan 2015–2016

Rural livelihood in western Rajasthan is basically dependent on crops and livestock production. So, the marginal lands in the semiarid region of India offer potential for fodder production to feed the cattle population which is an integral component of farming practice of this region. Paying attention to these areas can solve the problems of pulses, oilseeds, and cotton. The dry land areas have also tremendous potentiality of increased food grain production (Varghese and Mordia 2019). Thus enhanced agricultural production in these areas would boost the culture-based economy of India. Moreover, it would also be helpful in eliminating the problem of hunger and malnutrition that prevails in the “below poverty line” society of the country.

Challenges to Small and Medium Land Holding Farmers

Owners of small and medium holdings face extensive challenges as they seek agricultural growth, food security, and livelihoods in dry lands, particularly regarding access to inputs and marketing. They are usually dependent on other large farms to access land, water, inputs, credit, technology, and markets. They find adapting to climatic changes difficult and face challenges on liberalization effects, globalization effects, integration of value chains, market volatility, and other risks. A major paradox in dry land economy is that the decline in the share of agricultural workers in the total number of workers has been slower than the decline in the share of agriculture in the total GDSP.

The average size of land holdings in western Rajasthan declined from 8.26 hectares in 1990–1991 to 5.6 hectares in 2010–2011. As such, 33% of land holdings belong to marginal farmers with less than 1 hectare land, i.e., 2.5 acres. The average size of marginal holdings in western Rajasthan is less than 0.25 hectares and that of small holdings is 1.45 hectares. It poses a great challenge to dry land farming.

Food Security Analysis

The ultimate objective of the agriculture development is to get self-sufficiency in food, feed, fodder, and milk and meat production and insure the availability of food to the poorest of the poor citizens (Anjani 2012; Pandey 2015). Nutritional quality of food is the most important parameter for maintaining human health and complete physical well-being (Kumar et al. 2012). Since nutritional well-being is the driving force for the development and maximization of human genetic potential (Radhika et al. 2011). Based on the food security atlas of rural Rajasthan (IHD 2009), various parameters and indicators are analyzed (Tables 14.6 and 14.7) to find out the food security in arid Rajasthan.

In per capita value of agricultural output, only Ganganagar and Hanumangarh districts have moderate value, while Churu, Jodhpur, and Pali have extremely low value. In the share of agricultural labor force, only Ganganagar gets high and Sikar moderate rank. In food availability index too, Ganganagar district is secure, while Hanumangarh and Jhunjhunu are moderately secure. In food security outcome index, Ganganagar, Hanumangarh, and Sikar are secure (Pareek et al. 2017). Barmer district is extremely insecure in most of the parameters. In food access index, only Jhunjhunu district is secure, while Pali and Jodhpur are severely insecure. The status in terms of food security index (FSI) shows Pali and Barmer as extremely insecure

Table 14.6 Intensity of cultivation, cropping intensity, and irrigation intensity in western Rajasthan (2007–2008 and 2015–2016)

District	Cropping Intensity (%)		Irrigation Intensity (%)		% net irrigated area to net sown area	
	2007–2008	2015–2016	2007–2008	2015–2016	2007–2008	2015–2016
Barmer	106	112	154	144	5.84	14.94
Bikaner	113	124	159	176	9.89	26.74
Churu	124	119	129	155	4.02	12.60
Ganganagar	145	167	157	184	70.61	77.17
Hanumangarh	151	153	182	188	38.19	49.24
Jaisalmer	113	128	155	285	7.96	14.97
Jalor	126	138	119	115	30.96	52.08
Jhunjhunu	153	158	126	109	50.52	56.39
Jodhpur	110	124	148	167	10.10	31.53
Nagaur	115	119	134	137	19.18	22.02
Pali	114	120	106	108	15.83	26.90
Sikar	141	142	133	125	41.52	46.36
Total	122	134	142	158	25.39	35.91

Source: Agricultural Statistics, Rajasthan, 2009–2010 and 2016–2017

Table 14.7 Food security parameters in western Rajasthan

District	Per capita value of agricultural output	Food availability index	Food access index	Status in term of FSI	Food security outcome index
Barmer	Extremely low	Extremely insecure	Moderately secure	Extremely insecure	Extremely insecure
Bikaner	Very low	Severely insecure	Moderately insecure	Severely insecure	Moderately secure
Churu	Extremely low	Severely insecure	Moderately secure	Moderately secure	Moderately insecure
Ganganagar	Severely insecure	Severely insecure	Severely insecure	Severely insecure	Severely insecure
Hanumangarh	Moderate	Moderately secure	Moderately secure	Moderately secure	Secure
Jaisalmer	Extremely low	Extremely insecure	Moderately insecure	Severely insecure	Moderately insecure
Jalor	Very low	Moderately insecure	Moderately insecure	Severely insecure	Moderately insecure
Jhunjhunu	Very low	Moderately secure	Secure	Secure	Moderately secure
Jodhpur	Extremely low	Severely insecure	Severely insecure	Severely insecure	Moderately secure
Nagaur	Very low	Severely insecure	Moderately insecure	Severely insecure	Moderately insecure
Pali	Extremely low	Severely insecure	Severely insecure	Extremely insecure	Severely insecure
Sikar	Very low	Moderately insecure	Moderately secure	Moderately secure	Secure

Source: Food Security Atlas of Rural Rajasthan, 2009

districts, Jhunjhunu as secure, and Ganganagar, Hanumangarh, and Sikar as moderately secure districts. The remaining Bikaner, Jaisalmer, Jalor, and Nagaur districts show moderate status in food security (Table 14.8).

Development Measures

The major challenges for the sustainable development of agriculture in arid Rajasthan are to increase the productivity and production stability of rainfed crops, achieve food and fodder security, increase water use efficiency, reversal of land degradation, minimization of risk, and intensive labor absorption (Chakrabarty 2016; Ritchie et al. 2018). The important measures in this direction are to boost agricultural productivity in dry lands, promotion of low/zero tillage, in situ moisture conservation through raised bed, ridge, furrow, mulching, etc.; develop climate hardy crops; improve water use efficiency; increase and maintain green cover by reducing losses to agricultural lands due to grazing; eco-restoration of grazing land;

Table 14.8 Development indicators in arid western Rajasthan

District	Change in human population 1970–2011	Change in average size of land holding* (1990–1991 to 2010–2011)	Index of level of development	Food availability index	Food insecurity situation**
Barmer	236.14	13.77–7.98	24.65	Very low	Moderately insecure
Bikaner	313.11	12.05–8.75	35.28	Very low	Secure
Churu	133.43	10.86–5.85	33.62	Very low	Secure
Ganganagar	168.95	6.70–7.42 4.93	46.88	Moderate	Moderately secure
Hanumangarh			33.61	Low	Moderately secure
Jaisalmer	302.97	15.44–8.72	28.60	Extremely low	Moderately insecure
Jalor	174.0	6.24–4.94	33.78	Extremely low	Extremely insecure
Jhunjhunu	130.26	3.07–1.77	35.67	Low	Secure
Jodhpur	219.74	9.25–7.10	39.71	Extremely low	Moderately secure
Nagaur	162.19	6.21–4.38	31.54	Extremely low	Moderately secure
Pali	110.16	3.97–3.56	40.61	Very low	Moderately insecure
Sikar	156.82	3.37–1.96	32.58	Low	Secure
Total	176.47	8.26–5.60	34.71		

Source: Rajasthan, World Food Program, New Delhi

use of sustainable and low-emission technologies; develop organic farming modules to be disseminated; improve land condition for agriculture; green manuring and organic farming; use of solar pump for drip irrigation; harnessing potentials of crop productivity and allowing advance decision making at the farm level; improve animal feeding technology modules; assessment of epidemiology of climate-sensitive disease of animals; ensure availability of certified quality seeds; and rodent control; and reduction in fluoride level in drinking water.

Other measures are direct income support for farmers, protected markets, recognize small and marginal farmers as a special group, enhancing value of their produce and production, integrated pest management, farm tools and equipment popularization, improved germplasm of sheep, cattle, buffaloes, and camel for enhancing milk, wool, and meat production, area-specific mineral supplement compound feed block and rumen-bypass of technology, field-based diagnostic kit, and value addition of milk and other farm produce.

Judicious Use and Management of Groundwater

For judicious use and efficient management of groundwater and increase of water use efficiency, the important measures are to minimize loss in conveyance, minimize loss from the point of delivery, minimize loss in water application, minimize operational loss, growing of less water-requiring crops, appropriate scheduling of water application, use of drip and sprinkler system of irrigation, artificial recharge, provide incentives for water conservation and artificial recharge, groundwater modelling, and suitable legislation should be promulgated for the controlled use of water (Gupta and Ojaswi 1996).

Development of Sustainable Rainfed Agriculture System

The important strategies for developing such lands are wind erosion control, development of agroforestry models, field boundary plantation, in situ water harvesting and soil moisture conservation through contour furrows, contour bunding, and vegetative barriers; adoption of suitable tillage and sowing practices, soil fertility management, taking suitable crop varieties matching with the rainfall pattern (Bhati 1997), crop-fallow rotation, mulching, developing short duration and drought-tolerant varieties, and strengthening local capacity to manage agriculture and natural resources. The highest priority should be given to improvement of tillage practices, controlling wind erosion through *kanabandi* (field bunding), strip cropping for soil and water conservation, weed management, integrated nutrient management, integrated pest management, wider spacing for rainfed pearl millet, development of disease and pest-resistant genotypes of oilseeds, and developing eco-friendly plant protection schedules for various crops (RAU 2007)

Other measures are to cultivate and promote indigenous technical knowledge (ITK) of desert people. For example, develop rainfed farming packages for cropping system under different timing of onset of monsoon, reliable weather forecast system, creation of alternate/supplementary employment, availability of quality seeds, effective penetration of agriculture extension program, poverty alleviation and women empowerment, management of crop residue, integrated pest management, postharvest technologies, and value addition of traditional crops and by-products (Gaur and Gaur 2004).

Improvement and Value Addition of Biomass Productivity

The strategies include maintenance of tree on nonarable land, around house, along boundaries and in other community sites; intercropping on arable land monocropping on arable farm woodlots and development of silvi-pasture with suitable blend of trees, shrubs, and grasses (Gaur et al. 2018a, b).

Modernization of Animal Husbandry, Dairying and Livestock Production

Enhancement of fodder production, creation of adequate fodder bank, availability of quality fodder and feed, development of livestock-based infrastructure facilities, dairy development, meat production, and efforts to make this profession more attractive with social status are important sectors for development (Gaur et al. 2018a, b). The important strategies could be the improvement of carrying capacity of pastures through regeneration, development, and management and development of silvi-pasture with a suitable blend of tree, shrub, and grass species. Other measures include adequate production of fodder during lean period, production of feed blocks and improvement of nutritious value of fodder, establishment of breeding farm for cattle, sheep, goat, and camel; and genotype improvement of local breeds, providing adequate veterinary facilities (including mobile dispensary) as per livestock population over the region. In addition, develop a mechanism for collection, chilling, processing, and marketing of milk and its by-products and mobilization and need-based training to pastoralist and credit facility. Social stigma should be removed with people's involvement for developing meat industry.

Development of Alternate Land Use Systems

The important alternate land use system for arid region are agroforestry, agri-horticulture, agri-horti-pasture, agri-silvi-pasture, silvi-pasture, horti-pasture, horti-silvi-pasture, and cultivation of medicinal and aromatic plants (Vittal et al. 2006).

Drought Proofing and Management

The agriculture is one of the major sources of livelihood that by and large depends on the monsoon; drought often leads not only to shortage of food, fodder, and water but also threatens livelihood sources. Long-term analysis of droughts shows that on an average, every 2.5 years is a drought year in the region. The major factors that accentuate the impact of drought in the region are poor water holding capacity of soils, absence of perennial rivers and forests, poor groundwater quality, high withdrawal from limited groundwater reserve, a paradigm shift in land use, and neglect of the traditional coping mechanism that were basic to survival in an arid ecosystem (Narain and Singh 2002). Therefore, drought is no stranger in the region. The strategies include choice of crops, plant population management, preparation of rainfall distribution model for different situations, weed management, lifesaving irrigation, establishment of fodder and seed bank at *tehsil* (subdistrict) level, adequate vaccination program, inclusion of agro-industrial by-products and nonconventional feed, reserving more land for cultivation of fodder crops, and optimize overall crop production.

Conclusion

More than 75% of the farmers engaged in rainfed farming are small and marginal. Therefore, improvement in rainfed farming would raise the economic status of farmers thus helping in poverty alleviation. Rainfed farming holds immense significance especially in the context of fluctuating food grain production and expanding population in India (Ramakrishna and Rao 2008). Nearly two third area of western Rajasthan is under agriculture which includes 13.6% irrigated and 52.0% dry lands. The intensity of cultivation decreases from east to west with the declining rainfall. Irrigated area through groundwater is mainly concentrated in alluvial plains, interdunal plains, and valley fill regions. Canal irrigated area mainly concentrated in Sri Ganganagar, Hanumangarh, and Bikaner districts. Pearl millet, *Vigna aconitifolia* (moth), cluster bean, mung bean (*Vigna radiata*), and sesamum are important rainfed crops. Wheat, mustard, gram, groundnut, cumin, and Psyllium husk are important irrigated crops. The total crop production comes to 11.3 million tonnes. During the last 48 years, the irrigated and doublecropped area has significantly increased. On the other hand, long fallowing practices have been largely abandoned due to division of holdings and increase of population. Introduction of sprinkler system not only increased the area under irrigation but also helped to grow crops on the undulating sandy terrain. Production has registered increasing trend due to irrigation, fertilization, plant protection, and adoption of modern technologies. Mixed cropping system has also declined. More emphasis is now being given to cash crops. Agricultural development has taken place in areas when irrigation became possible. Due to uncertainty and instability of crop production, the rainfed areas cannot be relied upon to provide food security. Excessive irrigation, overexploitation of groundwater, and constant irrigation with saline/sodic water caused a sharp decline in water level and development of salinity/sodicity/waterlogging. Degradation of land and creation of new wastelands have also taken place. Despite this, the region still has scope for enhancing the productivity of dry lands, livestock-based integrated farming system, modernization of animal husbandry, dairying, and livestock production, development of silvi-pasture, and economic utilization of native flora.

To sum up, dry lands are the chief contributors of pulses, oilseeds, coarse grain crops, and cotton, and they also contribute significantly to wheat and rice production. Therefore, it is the need of the hour to adopt and practice the available dry land technologies for increased agricultural production, which would boost the food grain production of the country and would also improve the economic status of farmers as well as food and nutritional security in these areas.

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Chapter 15
Diversification and Land Use Management Practices for Food and Nutritional Security Under the Climate Change Scenario in Arid and Semi-arid Regions of India

P. K. Pankaj, Mahesh K. Gaur, G. Nirmala, V. Maruthi, Pushpanjali, Josily Samuel, and K. S. Reddy

Context and Setting

In India, rainfed agriculture constitutes 55% of the total net cultivable area and contributes to production of major coarse cereals, pulses and oil seeds. By comparison, rainfed and arable areas constitute about 93% of sub-Saharan Africa, 87% of Latin America, 67% of the Near East and North Africa, 65% of East Asia, and about 58% of South Asia (FAO 2002). Apart from this, most countries depend primarily on rainfed agriculture for their grain food. The environment of rainfed agriculture is characterized by regular climatic constraints like long dry spells, high-intensity rainfall, high evaporation losses, soil degradation, etc., which are becoming more intense with the onset of climate change. Moreover, the annual average rainfall varies from less than 100 mm to 2500 mm in different rainfed agro-ecological regions of India. Rainfall distribution is erratic with the coefficient of variation (CV) varying from 30 to 80% during the crop growth period and varying in both space and time. The present level of land productivity in rainfed agriculture in India is about 1 t/ha; however, globally it varies from 1 to 2 t/ha (FAO 2002). In India, the Semi-arid tropics (SAT), spread over 175 districts, amounts to 37.2% of the geographical area of the country (Map 15.1), supporting 36.9% of the population and covering 42.9% of the country's gross cropped area and 46.2% of the Net cropped area (Rao et al. 2005). Changes in irrigation percentages, shifts in consumption patterns and technology advances have brought changes to cropping patterns in arid and semi-arid regions of India (Reddy et al. 2017).

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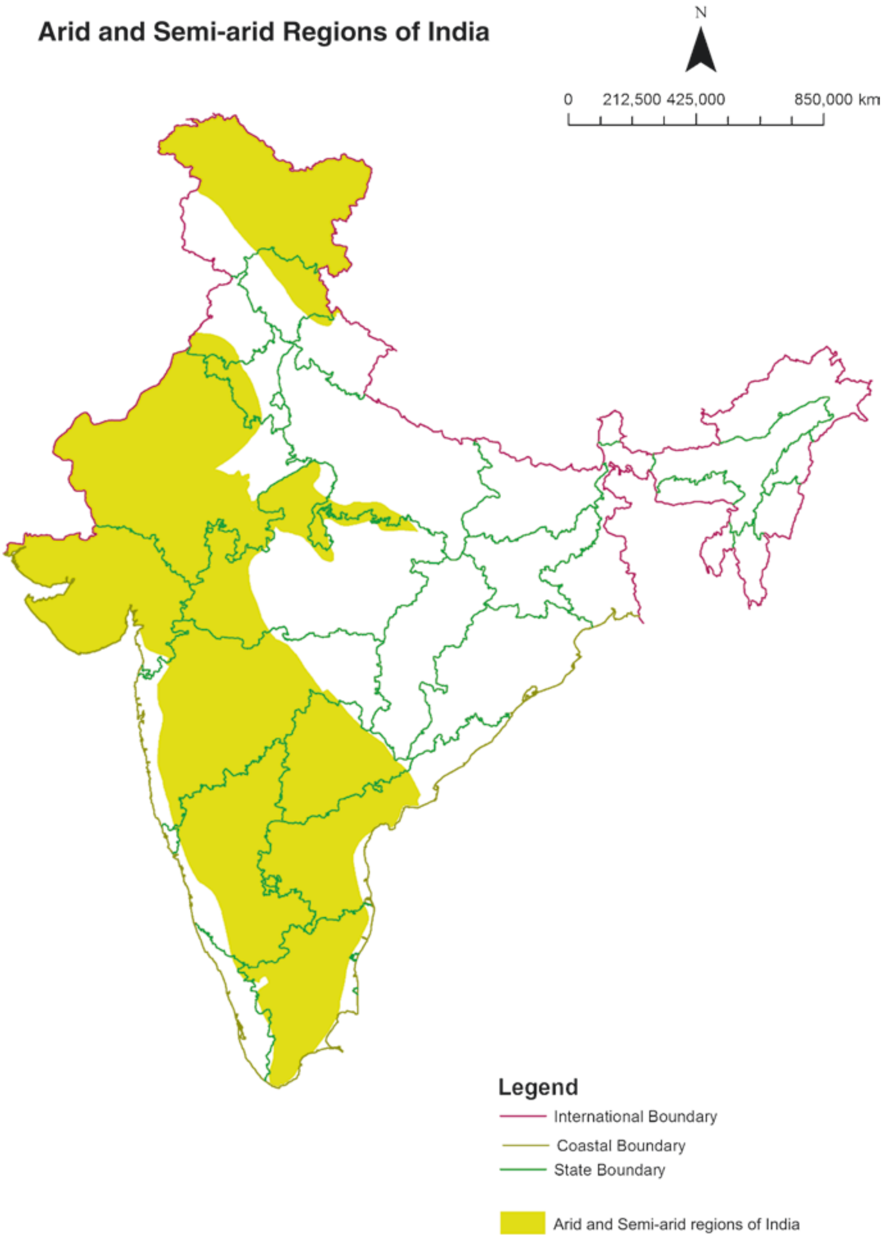


Map 15.1 Arid and semi-arid regions of India, with state boundaries (Compiled by author)

However, the majority of farmers own less than one hectare of land that is fraught with problems of frequent droughts, land degradation, soil erosion, infertile soils and poor socio-economic conditions. The Indian hot arid zone occupies an area of 32 million hectares (Mha) constituting about 10% of the country's geographical area. It forms a continuous stretch in the north western states of Rajasthan (61%), Gujarat (20%), Punjab (5%) and Haryana (4%), and scattered landmasses in the peninsular states – namely, Maharashtra, Karnataka and Andhra Pradesh. Inadequate quantities and erratic distribution of rainfall (<150 mm to 400 mm, CV 36 to >65%) coupled with high evaporative demand (1600–1900 mm/year) and light-textured soils have made agriculture a difficult proposition. The incidence of poverty has been found to be the highest in SAT when compared with the other agro-ecological regions. The agricultural output of the gross cropped area is lowest in arid and semi-arid areas (0.77 and 0.86%, respectively) when compared with humid areas (1.26%) and this is because of low irrigation coverage, marginal soils and low rainfall.

Agriculture plays a vital role in the Indian economy, which accounts for 18% of India's gross domestic product (GDP), and 55% of the population is dependent on agriculture (Kumar et al. 2015). Hence any change in the crop conditions, including the fact that nearly 52% of the total cultivated area is being cropped under rainfed conditions, is likely to affect the overall economy of the country (Naresh Kumar et al. 2014; Parmeshwar et al. 2014). The Indian agriculture sector is dominated by marginal and small farm holdings able to consume nearly 80% of the total freshwater (Hochman et al. 2017). In the semi-arid tropics, dryland agriculture relies on rainfall as the major source of water (Wani et al. 2012). Indian agriculture currently faces a host of diverse challenges due to the ever-growing population, increasing food and fodder needs, natural resource degradation, higher cost of inputs and climate change (Pankaj et al. 2017). Supplemental irrigation and water harvesting are the most important and proven technologies for improving crop productivity as is efficient use of water in the dryland areas of the semi-arid tropics. These technologies integrated with crop diversification can increase farmers' income in dryland agriculture systems with improved nutrient availability and food security among the farmers. The monthly per capita expenditure is also lowest in semi-arid areas compared to arid and humid regions of the country. As a result, the incidence of poverty is higher in semi-arid areas than in arid areas. About 60 million of India's 147 million rural poor live in rural semi-arid regions (Rao et al. 2005).

Production intensification or land diversification is the key to agricultural sustainability. After achieving food sustenance for families, crop intensification/diversification becomes a mainstay for commercial agriculture. To reduce pressure on water resources, better-quality rainfed lands could be brought under either limited or unlimited irrigation during the post-rainy season (Lu 2003). The traditional farming systems are self-contained and show resilience to aberrant weather conditions, but are low yielders.

The present chapter has been designed to explain the twin benefits of diversification (using cropping systems, livestock and horticulture) as well as land use management (soil management, carbon sequestration) coupled with socio-economic development in the arid and semi-arid regions of India to maintain food and nutritional security (FNS) under a climate change scenario.

Climate Change Scenario in Arid and Semi-arid Regions

Arid regions cover about 12% of the geographical area of India, comprising 31.7 Mha hot arid and 7.0 Mha cold arid regions. Nearly 90% of the hot arid regions of India lie in the northwestern states of Rajasthan (19.6 Mha), Gujarat (6.22 Mha), and Haryana and Punjab (2.75 Mha). Some small pockets (3.13 Mha) of the hot arid zone are in the southern states of Andhra Pradesh, Maharashtra and Karnataka (Table 15.1 and Fig. 15.1). The arid region of northwest India constitutes the major part of the Great Indian Desert or the Thar Desert. About 85% of the Thar Desert lies in northwest India and the remaining part is in southeast Pakistan. The Thar Desert accounts for 89.6% of the total hot arid regions of India. The climate of the hot arid regions is characterized by low and erratic rainfall, high potential evapo-transpiration, wide diurnal and annual temperature ranges, high solar radiation, low relative humidity and high wind velocity. The annual rainfall ranges from about 100 mm in the extreme west to 500 mm in the east and southeast, while the potential evapo-transpiration is about 1650 mm in the east, increasing to over 2000 mm in the west. The coefficient of variation of annual rainfall varies from 35% in the east to 65% in the west. Most of the rainfall (80–85%) is received during the southwest monsoon season (June–September) of the Indian sub-continent. However, monsoon rains start in the first week of July and usually withdraw by September, beginning in the hot arid zone of northwest India. The region experiences extremes in temperatures. The air temperature increases sharply from April and peaks during May to mid-June. Maximum temperatures during summer vary from 36 to 43°C in the eastern and 39 to 45°C in the western parts but occasionally may reach up to 50°C. During

Table 15.1 Characteristics of arid and semi-arid eco-regions of India

Climate	Annual rainfall (mm)	Moisture index (%)	Growing period (days)	Physiography	Area (Mha)
Arid					
Cold arid	<500	<–66.7	60–90	Western Himalaya, Jammu and Kashmir	14.3
Hot arid	<500	<–66.7	<90	Western plains and Kutch, Deccan plateau	31.7
Semi-arid					
Dry	500–700	–66.7 to –55.8	90–120	Northern plains, central highlands, Deccan plateau, Tamil Nadu uplands, south Tamil Nadu plains	41.6
Moist	750–1000	–55.7 to –33.3	90–150	Indo-Gangetic plains, Bundelkhand uplands, Malwa plateau, Eastern Gujarat plain, Vindhya hills, part of Maharashtra, Karnataka, Vidharbha, Telangana, Karnataka, Tamil Nadu, Punjab and Rohilkhand	72.2

Source: Srinivasarao et al. (2013)

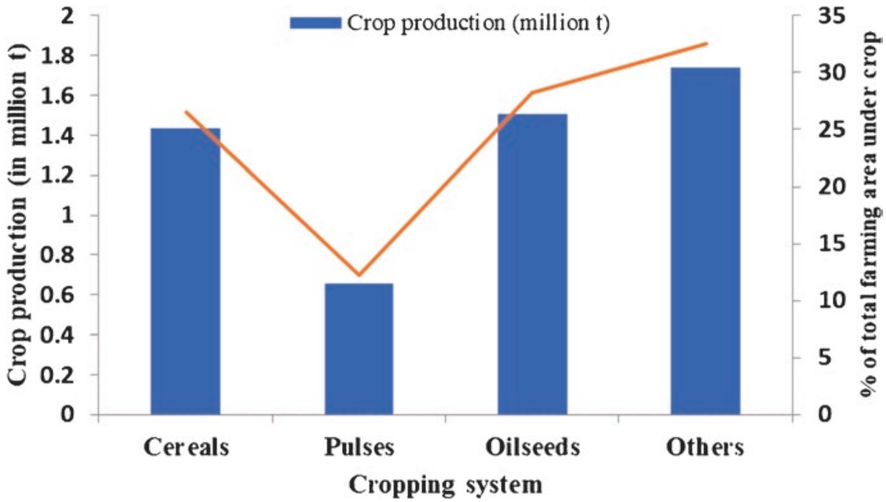


Fig. 15.1 Production and area under different cropping systems in western Rajasthan (2015–2016) (Source: Agricultural Statistics, Rajasthan (2015–2016))

winter, the maximum air temperature varies from 24°C in the east to about 26°C in the west. Sub-zero temperatures are not uncommon and minimum temperatures during winter may be as low as −5°C on sandy terrains. Soil temperature fluctuations reflect the diurnal and annual cycles of the air temperature.

Arid and semi-arid regions cover 30% of the total area in the world and are inhabited by 1.10 billion people (20% of the world population). Arid and semi-arid regions are home to 24% of the population in Africa, 23% in Asia, 17% in the Americas and Caribbean, 6% in Australia and Oceania, and 11% in Europe. Highly populated, water-limited and warm drylands are challenging areas for development and are expected to expand overall under several scenarios of climate change (Rajaud and Noblet 2017). A purely climatic definition uses the precipitation (P) to potential evapo-transpiration (PET) ratio (aridity index). Different levels of aridity are distinguished based on consensual thresholds (Yukie and Otto 2011): 0.65 (sub-humid), 0.5 (semi-arid), 0.2 (full arid) and 0.05 (hyper-arid). The projected area-averaged annual mean warming over land regions of Asia is likely to be 1.6 ± 0.2°C in the 2020s, 3.1 ± 0.3°C in the 2050s and 4.6 ± 0.4°C in the 2080s. Similarly, the projected area-averaged annual mean increase in precipitation is likely to be 3 ± 1% in the 2020s, 7 ± 2% in the 2050s and 11 ± 3% in the 2080s.

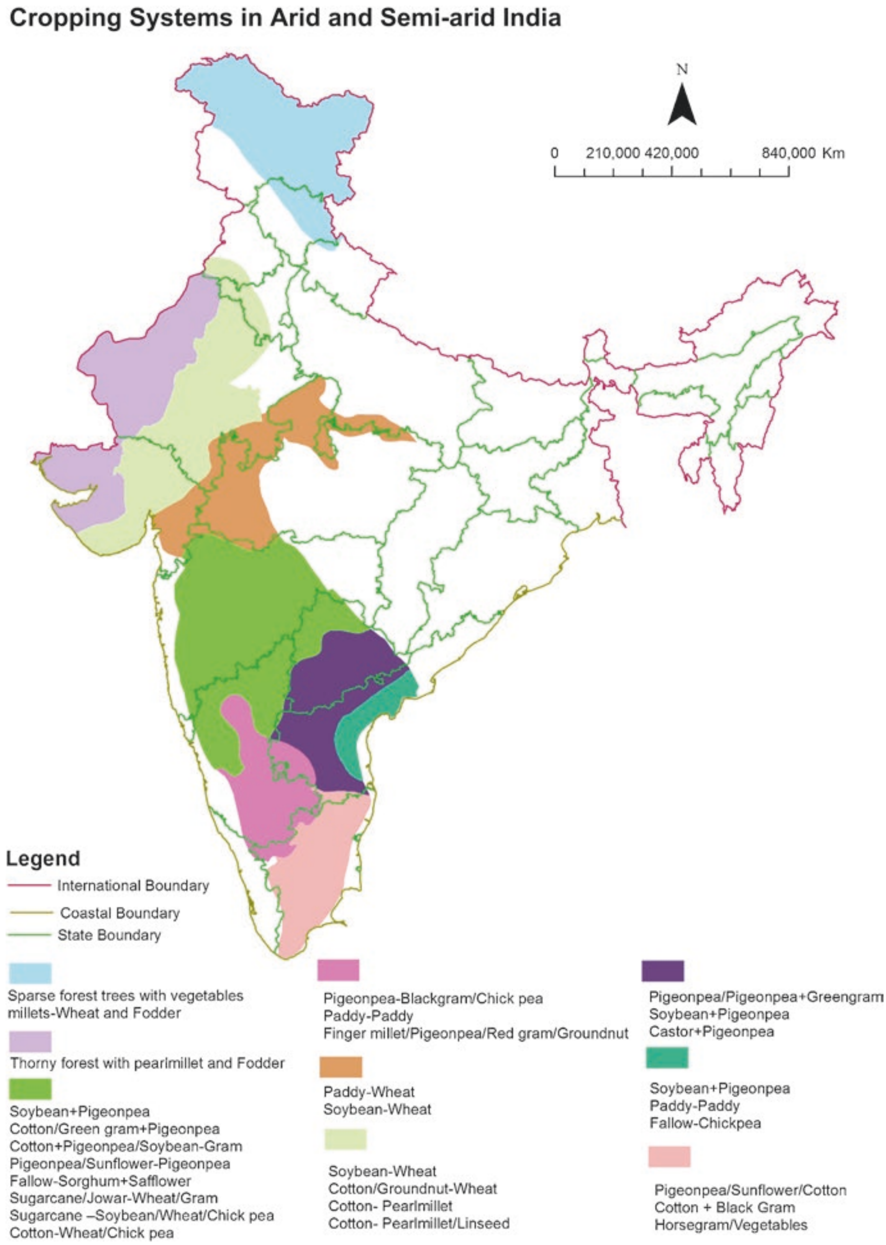
Crops and Cropping Systems in Arid and Semi-arid Regions

Although semi-arid tropics (SAT) are typically characterized by low and uncertain rainfall and poor quality of soils, which affect both the quantity and value of the agricultural output, they have been defined differently by different analysts. The cropping patterns in this broadly defined SAT region have undergone substantial changes due to increased coverage under irrigation, shifts in consumption patterns, and changes in technology and market prices. The integrated farming system (IFS) approach has been widely advocated for improving productivity, profitability, livelihood and soil health under different agro-ecological settings in India (Gill et al. 2009; Surve et al. 2014; Sahoo et al. 2015; Balamati and Shamaraj 2017; Pankaj 2018).

Improving the productivity of annual crops will remain the focal point for improving the productivity of any farming system in arid and semi-arid regions. The key elements for improvement of crop productivity envisaged for these regions are efficient rainwater management, suitable tillage and sowing operations, selection of improved varieties, appropriate inter-cropping and crop rotation systems, efficient soil fertility management, proper plant protection measures and contingency crop planning. However, positive impacts of these interventions on yields are more perceptible only in normal to mild-drought years, causing farmers' reluctance to adopt these improved dryland farming technologies (Bhati 1997; Jodha et al. 2012).

Inter-cropping of cereal and pulse crops is traditionally practiced in semi-arid tropic (SAT) regions of India as a risk-coping mechanism for minimizing drought impacts especially for small and marginal farmers (60% of farmers in rainfed areas) and in arid regions with cotton-based or pulse-based cropping systems (Map 15.2). Inter-cropping has the advantages of maximized rainfall utility both spatially and temporally, minimized risk in terms of crop failures and optimum utilization of weather resources like light to make it profitable and stable (Singh and Reddy 1986; Maruthi et al. 2019). Therefore, inter-cropping is practiced for more total system productivity and economic stability of the farmers (Gliessman 1981). Due to labour scarcity and unavailability of appropriate farm implements (Sanjeeva Reddy et al. 2019) and suitable herbicides, inter-cropped areas have been declining. Since the advantages of inter-cropping are lost, the replaced sole crops have been suffering soil moisture stress, and sometimes they may even fail. Further, with the shifts from inter-cropping to sole commercial cropping, future food security issues are surfacing. Consequently, the Food and Agriculture Organization of the United Nations (FAO) (2012) has suggested agro-ecosystem-based crop diversification as well as intensification.

In western Rajasthan (a major arid region of India), over most of the area, food grains (cereals and pulses) are produced, followed by oilseeds and other crops (Fig. 15.1). This tells much about the natural resilience of diversification holding the key to low rainfall and high temperature. The long-term trends regarding intensity of cultivation, cropping intensity and irrigation intensity in western Rajasthan were followed by comparing the data from 2007–2008 and 2015–2016 (Fig. 15.2). It was observed that installation of a water management system is vital as it underpins sustainable agriculture even in the arid part of the country. With regard to the principal crops grown in the most arid part of the country, western Rajasthan, the increases in the areas of pearl millet, pulses, mustard, groundnut and gram were found to be the largest (Fig. 15.3). The most positive jump in the area of production, as compared to the year 1970–1971, was seen in the cases of groundnut, mustard and gram; however, all of the above-mentioned crop areas in the region were significantly increased. When the production of crops in the same zone was followed, it



Map 15.2 Cropping systems in arid and semi-arid regions of India, with state boundaries (Compiled by author)

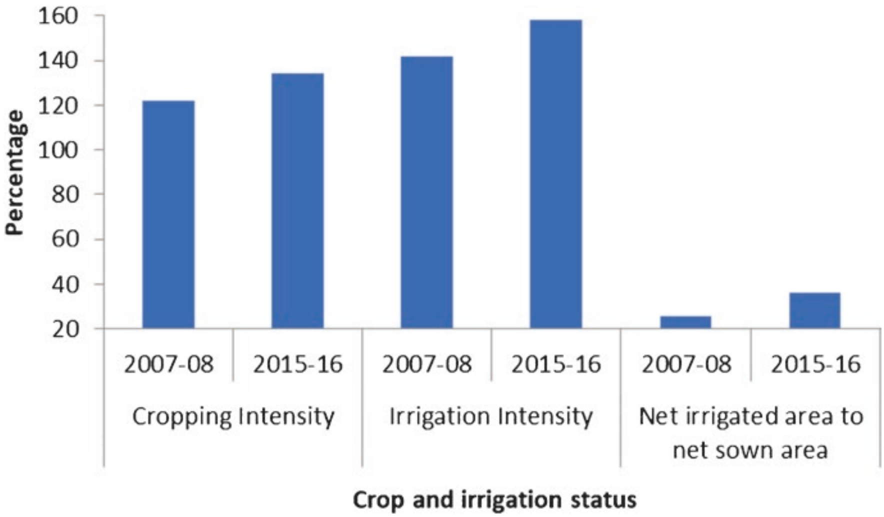


Fig. 15.2 Intensity of cultivation, cropping intensity and irrigation intensity in western Rajasthan (2007–2008 and 2015–2016) (Source: Agricultural Statistics, Rajasthan (2015–2016))

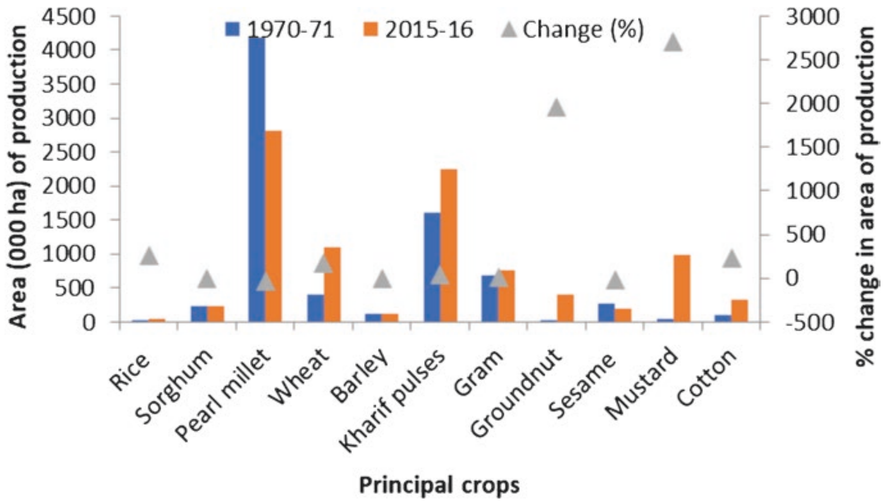


Fig. 15.3 Trend in area of principal crops in western Rajasthan (Source: Agricultural Statistics, Rajasthan (2015–2016))

was found that production of groundnut was tremendously improved (Fig. 15.4). Except for pearl millet, production of all other crops (rice, sorghum, pearl millet, wheat, barley, kharif pulses, gram, sesame, mustard, cotton) was also improved.

In order to improve the productivity of oilseeds and pulses in peninsular India (contributing more than 80% of production in rainfed regions), intensification is one option but has the disadvantage of excessive exploitation of natural resources. Sustainable crop intensification can be an effort to intensify cropping systems with

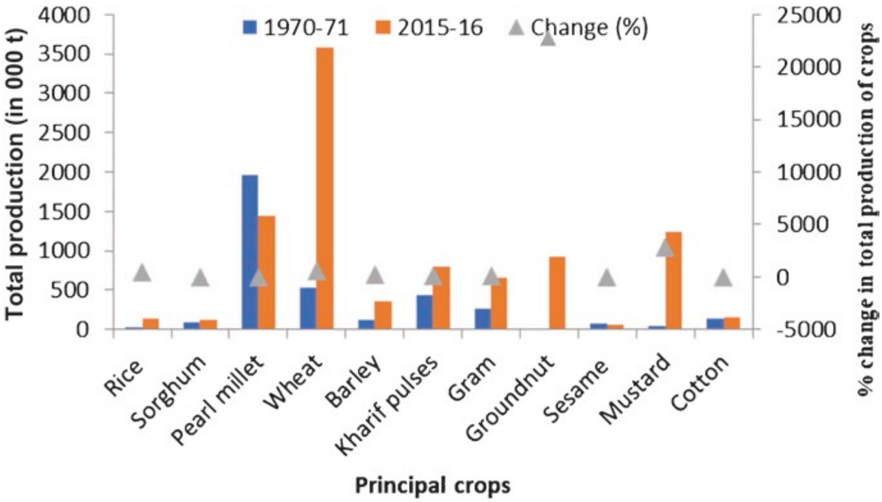


Fig. 15.4 Trend in production of principal crops in western Rajasthan (Source: Agricultural Statistics, Rajasthan (2015–2016))

balanced utilization of land, water, energy and other inputs (agri-ecosystem) which are in short supply (Pretty et al. 2011, Murungweni et al. 2016). An approach of crop intensification as well as an integrated farming system involves a logical blend of both crops and livestock for enhancing crop productivity wherein better food security in the future can be achieved with suitable combinations of crop intensification and diversification in these areas (Maruthi et al. 2017a).

Changes in Soil Properties Due to Changes in Land Use

Soils under the forest system were used as a control to evaluate the changes in soil properties due to land use and management interventions in two managed systems. The soils in horticultural systems had the highest pH (6.4) and the agricultural soils had the lowest pH (5.9), indicating that agricultural management interventions increased the acidity of these soils. The pH of the soils tended to increase with depth in all three systems. The average bulk density of the surface soils in the forest system (1.5 Mg m^{-3}) is low due to high soil organic carbon (SOC) when compared to the other two systems. Deforestation and subsequent cultivation result in an increase in soil bulk density (Hajabassi et al. 1977). Bhattacharyya et al. (2007) observed a negative correlation between bulk density and organic carbon in soils in different bioclimatic zones of India. The bulk density in the agriculture and horticulture systems decreased with depth.

Horticulture in Arid and Semi-arid Regions

In arid regions where livestock are a major component of the farming system, a horti-pastoral system forms an efficient drought-coping mechanism. *Ziziphus nummularia* (*jharberi*) is an important top feed species in arid regions and almost every part of it has a use. The leaves make excellent fodder, having high crude protein (13–17%) and fibre (15%).

Soil erosion by wind is one of the foremost problems in the Indian arid zone. Shelterbelts minimize the harmful effects of strong winds and increase farm productivity through moderation of the micro-environment at the field level. The terms 'shelterbelts' and 'windbreaks' are often used inter-changeably, but a distinction can be made. A shelterbelt is a long belt of shrubs and trees for protecting fields, whereas a windbreak is protective planting around a farm, orchard or building. Shelterbelt technology involves raising of porous vegetative barriers comprising strips of trees, shrubs and bushes planted across the direction of the prevailing wind. An increase of 305.6% in net returns has been observed by shifting from non-shelterbelt to shelterbelt use on farms in the Jaisalmer district (Gajja et al. 2008). Volumes of data on shelterbelts have been generated, addressing designs, composition, suitable tree species, planting techniques, etc. (Mertia et al. 2006). Contour vegetative barriers (CVBs) may also be designed using locally available fast-growing perennial grasses with extensive root systems (such as *Cymbopogon jwarancusa, Cenchrus ciliaris* and *Cenchrus setigerus*) transplanted 0.3 m apart on contours at a 0.6–1.0 m vertical interval, forming a dense hedge (Sharma et al. 1999).

Land Use Management Practices in Arid and Semi-arid Regions

In India, the current net sown area is 43% of the total geographical area (328 Mha), which has remained constant since 1970–1971 However, the gross cropped area has expanded from 166 Mha to 198 Mha during the same period. India has already lost some of its landmasses (30 Mha for ecologically productive areas, 19 Mha for infrastructure and housing); however, 25 Mha is still fallow land available for cultivation. Although the area devoted to food grain crops has remained unchanged (~124 Mha), rice- and wheat-growing areas have expanded from 56 to 75 Mha, at the cost of a fall in the area under coarse grain cereals.

Low and erratic rainfall, extremes of seasonal temperature, high evaporation loss, meager groundwater potential, absence of perennial streams, salinity and rocky/gravelly terrains are the major factors affecting the land use in hot arid regions of India (Ram and Lal 1998). In order to minimize adverse environmental effects, farmers in desert areas have evolved certain well-contained systems that follow a pattern in accordance with the rainfall (Fig. 15.5). Areas receiving <250 mm of rainfall have a predominance of grasses and shrubs; hence range/pasture development with livestock rearing becomes a major proposition. In the

250–350 mm rainfall zone, besides grasses and shrubs, multipurpose tree species dominate the landscape. Mixed farming encompassing agro-forestry systems, mixed cropping, livestock and pasture management are the main livelihood options. Where rainfall is more than 300 mm, crops and cropping system diversification, agro-forestry and livestock rearing are the major systems of sustenance of arid-zone farmers (Bhati and Joshi 2007). These sustainable systems, although resilient to weather aberrations, have low production levels, which are now inadequate to fulfill the needs of an ever-increasing population and its aspirations. Suitable land use models have been developed by different authors for different agro-eco-regions of India (Table 15.2).

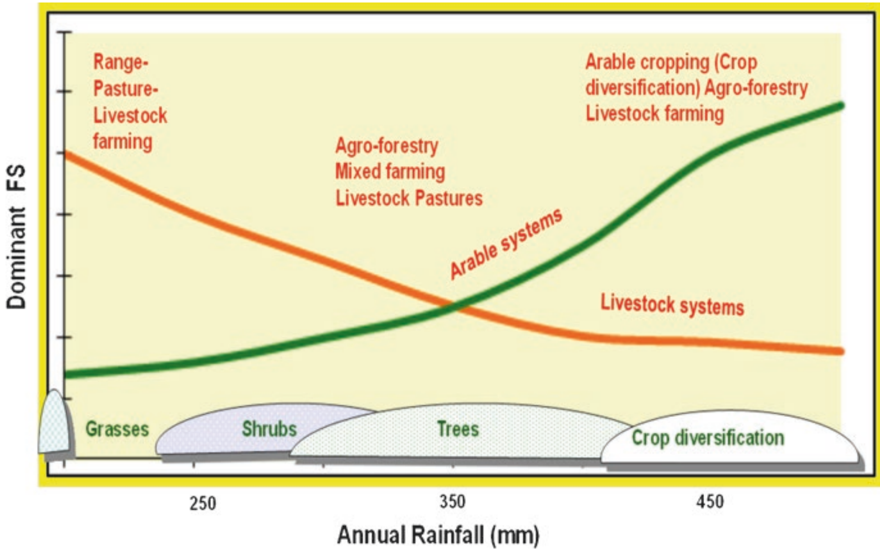


Fig. 15.5 Dominance of various farming systems (FS) according to rainfall patterns in the arid zone (Source: Bhati and Faroda (1998))

Table 15.2 Suitable integrated farming system (IFS) models for arid and semi-arid regions of India

Region	Land use IFS model	Reference
Karnataka	Crop (0.74 ha) + horticulture (0.18 ha) + fodder drop (0.02 ha) + livestock (2 cows, 1 buffalo)	Basavanneppa and Gaddi (2017)
Dryland western zone of Tamil Nadu	Sorghum + cowpea grain, sorghum + cowpea fodder and *C. glaucus* each in 0.33 ha inter-cropped with *Emblica officinalis* + a goat (5 + 1)	Radhamani (2001)
Semi-arid Gujarat	Crops: Pearl millet–wheat (0.44 ha), mustard–pearl millet (0.22 ha), cotton–fodder sorghum (1 ha) + horticulture: papaya (0.04 ha) + dairy buffalo (6)	Patel et al. (2007)
Semi-arid irrigated Punjab	For 2 ha land: crop (1.14 ha) + dairy (0.22 ha) + fishery (0.56 ha) + piggery (0.24 ha)	Gill et al. (2009)
Arid Rajasthan	IFS for 7 ha land (Table 15.3)	Tanwar et al. (2016)

Land Use Model for Arid Regions

Land use for all farming systems in arid Rajasthan decreased from 1976 to 2015 except for water bodies and forests (Fig. 15.6) which suggests improvement in water-harvesting structures and use of forest land for agriculture and other activities. A fixed land use model for an arid region was developed (Table 15.3) at the Indian Council of Agricultural Research (ICAR) Central Arid Zone Research Institute (CAZRI), Jodhpur, India, for farmland of 5–7 ha situated in the arid zone (rainfall 300–400 mm). For a sustainable farming situation in the region, it was allotted an area as per its optimal profitability and resource use efficiency. The net returns calculated from this IFS model were Rs. 70,000/ha with a payback period of

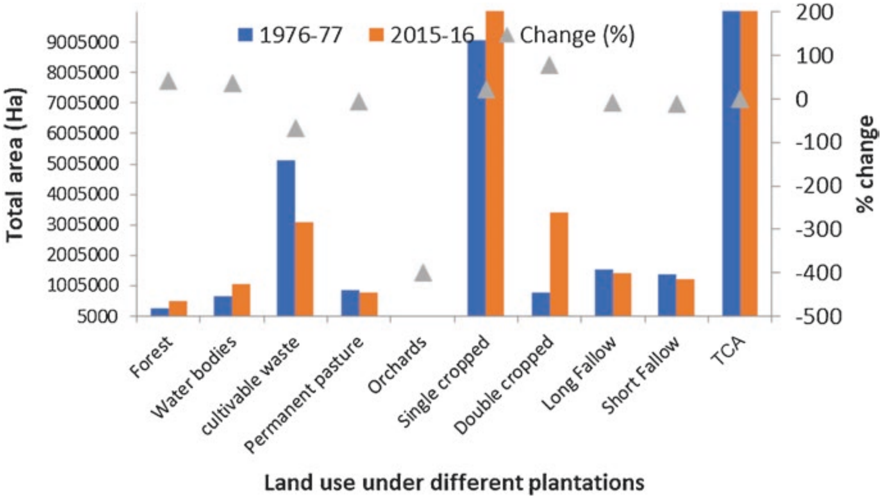


Fig. 15.6 Land use in arid Rajasthan (1976–1977 and 2015–2016). *TCA* total cropped area (Source: Gaur (2016))

Table 15.3 Synthesized rainfed integrated farming system (IFS) model for the arid zone (Tanwar et al. 2016)

System	Component	% area allocation
Arable cropping	Diversified cropping of pearl millet, greengram, clusterbean in 4:1:1 ratio Replace 30% pearl millet with dew gram under delayed monsoon	20
Agro-forestry	*Prosopis* + crops	30
Agri-horticulture	Ber + crops	20
Silvi-pasture	*Hardwickia* + grass (*Cenchrus ciliaris*)	10
Horti-pasture	*Ziziphus* + grass (*Cenchrus ciliaris*)	10
Boundary plantation	*Acacia*, *Hardwickia*, *Dalbergia* + trenching after 3 years of plantation	10
Cattle	Tharparkar breed	0.75 ACU/ha
Goas and sheep	Marwari breed	3 animals/ha

ACU adult cattle units

5 years at an internal rate of return (IRR) of 33%. This IFS model generated employment to the tune of 130 man-days/ha. This diversification was also equally effective in providing ecosystem services, viz. enhanced biodiversity, carbon sequestration, fuelwood production and greenery in the desert. In arid regions where livestock are a major component of farming systems, a horti-pastoral system forms an efficient drought-coping mechanism.

Land Use Model for Semi-arid Regions

A long-term investigation (2004–2011) was carried out on an alfisol watershed model (Picture 15.1) at an ICAR-CRIDA (Central Research Institute for Dryland Agriculture) research farm, Hyderabad, India, covering an area of 1.65 ha, with three pediments consisting of an upper soil depth of 8.0 ± 4.3 cm (D_1) with low water requirements for grasses (19% of the area), a middle basin of depth 15 ± 4.4 cm (D_2) with arable crops and cropping systems such as sorghum + pigeon pea (2:1) and castor + cluster bean (1:1) (48% of the area) and a lower basin of depth 30 ± 12 cm (D_3) with agro-forestry systems (25% of the area) and vegetables (8% of the area) (Maruthi et al. 2017b). A farm pond of 650 m^3 capacity was dug at the lowest point of the watershed for rainwater harvesting and recycling as supplemental irrigation for the vegetables. *Glyricidia* plants were grown along the graded bunds to be used as mulch-cum-manure. Teak, henna and *subabul* plants were planted alternately to create an asset in the watershed area. Horticulture plants like papaya and drumstick were planted around the periphery of the farm pond. Data on rainfall characteristics, seed and fodder yields of arable crops, agro-forestry systems, grasses, bushes and other perennial crops, along with their economics, and rainfall use efficiency was collected for all years (2004–2011). The rainfall was categorized as deficit (<20% of normal as in 2004, 2009 and 2011), normal (750 mm long-term rainfall as in 2006 and 2007) and excess (>20% of normal as in 2005, 2008 and 2010) and evaluations of the farming system in different categories of rainfall years were carried out based on net income (in rupees), the B:C ratio, availability of food

Picture 15.1 On Farm Resource (OFR)-based farming system at ICAR-CRIDA, Hyderabad

grains, estimated fodder security for livestock, etc. The cost of production of the farming system (FS) module was two times more in deficit rainfall years (Rs. 21,239) than during normal rainfall years (Rs. 10,419) due to the gestation period required by the agro-forestry component (Rs. 10,019).

The net income from FS was highest in excess rainfall years (Rs. 22,142) as compared to normal (Rs. 9420) and deficit rainfall years (Rs. 243). A similar trend in the B:C ratio was also observed, where it was almost doubled during excess rainfall years (2.46) as compared to deficit rainfall years (1.27). Family food security was estimated through the crop component in the watershed-based farming system which suggested that cereals, oilseeds and pulses produced during excess rainfall years could be sufficient for 3, 1.24 and 8 persons in a year, whereas during normal and deficit rainfall years, requirements could be fulfilled for 2, 0.79 and 4 persons in a year. The numbers of dairy animals and small ruminants that could be supported with this farming system were almost 1 and 3, respectively, during all rainfall years, but during deficit rainfall, external inputs would be required for procuring deficit legume fodder. Scaling-up of such models is necessary to address the livelihood security of small farmers in rainfed areas.

Use of Land as a Green Fodder Belt for Natural Resource Management and Conservation

Soil erosion is a common problem in arid and semi-arid regions with slope percentages of 3% or more. Green fodder belt technology was trialled at ICAR-CRIDA, Hyderabad, for 5 years of experiments (2015–2019) to prevent sheet erosion in rainfed farming situations with the option of live-saving irrigation, if required, which could be applicable to the semi-arid and sub-humid agro-ecological regions. A permanent bed of *Brachiaria ruziziensis* of 2 m width needs to be established every 15 m across the direction of the slope (Picture 15.2 (a) and (b)). This technology is not a hindrance to mechanization in farmers' fields. This bed can be maintained for several years and has the potential to prevent sheet erosion in addition to providing forage for ruminants. Cutting of green fodder should be done 90 days after establishment and subsequently every 60 days. Thus, a minimum of five cuts can be harvested from the grass belt.

In the first year of the experiment a permanent bed (2 m width) of *Brachiaria ruziziensis* is established. For establishment of a 2 m × 2 m bed, 150 saplings of *Brachiaria* will be required. Thus, for 1 hectare of land, 7000 saplings will be required. This technology provides green fodder of 10–15 t ha^{-1} on a yearly basis which can sustain the green fodder requirement of 15–20 small ruminants or 1–2 cattle. Thus, it is very good technology for small and marginal farms without affecting the growth of other crops in between the green belts. The natural resource management (NRM) benefits include prevention of soil and nutrient loss, increased infiltration opportunity time inside the standing crop field and biomass yield of 10–15 t ha^{-1} in addition to the concurrent crop/grain yield (CRIDA Annual Report 2016–2017).

Picture 15.2 (**a**) *Brachiaria ruziziensis* fodder strip. (**b**) *Stylosanthes hamata* fodder strip

The Livestock Component as a Model of Diversification in Arid and Semi-arid Regions

Livestock Farming Systems

The farming systems in the arid zone are quite diverse with a variety of crops and cropping systems, agro-forestry, and livestock production. The changes in the quantity of rainfall received and its distribution pattern are leading to intermittent droughts during the cropping period, resulting in crop failures leading to debts and migration. Droughts occur once every 3–5 years either due to a deficit in seasonal rainfall during the main cropping season or from inadequate soil moisture availability during the prolonged dry spells between successive rainfall events. Several farming systems involving trees, fruit, grasses and crops have been studied by ICAR-CAZRI, Jodhpur, for their suitability in arid agro-ecosystems and compatibility of selected farming system components in agro-forestry, silvi-pasture, agri-silvi-pasture, agri-horticulture and horti-pastoral systems. Feed resources provide a direct link between crops and animals, and the interaction between the two largely dictates the development of such systems. It has been observed that areas in the <250 mm rainfall zone have a predominance of grasses and shrubs (Fig. 15.5); hence range/pasture development with livestock rearing is the major proposition for such areas. Areas in the 250–350 mm of rainfall zone are suitable for agro-forestry and mixed farming; while areas receiving more than 300 mm of rainfall are suitable for agro-forestry, arable crops, crop diversification and livestock rearing. The crop productivity is low mainly due to aberrant weather conditions and poor soil fertility. Livestock gives a much more stable income than crop farming since the possibility of out-migration avoids localized scarcity conditions, making it much more adapted to uncertain and erratic climatic conditions. Even in terms of rentability of investment, livestock farming surpasses crop farming. In general, pastoralism is the predominant practice in arid regions and arable farming is of less importance with few exceptions. With the increase in aridity from irrigated tracts to dry farming to pastoralism, households owning sheep, goats, and camels have increased. In spite of frequent droughts and famines, there is an increasing tendency among the farmers to keep large numbers of animals as walking capital.

The diversity of livestock resources in arid areas is very wide, both in variety and variability in terms of species, breeds, populations and unique genotypes. This diversity has been recognized as a vital resource for the sustenance of mankind. Judicious utilization and enhancement of the quality of these resources is important to ensure their sustainability to meet future demands. Nature has endowed arid areas with some of the best breeds of cattle (Tharparkar, Rathi, Kankrej, Red Sindhi and Nagouri), buffalo (Murrah, Surti, Mehsana and Banni), sheep (Marwari, Magra, Nali, Pugal, Chokla, Jaisalmeri, Kheri and Patanwadi), goats (Marwari, Sirohi/Parbatsari, Jhakarana and Kachehhi), camels (Bikaneri, Jaiselmeri, Kuchchi and Mewati, and the lesser known breeds Marwadi, Mewadi, Sindhi and Shekawati) and horses (Marwari (Malani), Kathiawad, Bikaneri and Jaiselmeri). Livestock breeds in the region have been developed and owned by local people over many generations and are the product of local knowledge about animal breeding. Indigenous breeds from an arid environment are not only heat tolerant but also able to survive, grow and reproduce even with poor seasonal nutrition and high parasite and disease pressure.

More than half (57.73%) of the total livestock population of Rajasthan is in the arid district of the state with a larger number of small ruminants. The ratio of livestock to humans is equal in the western arid parts and is about 0.8 in the semi-arid parts of Rajasthan. The number of livestock in the arid zone increased by 41% between 1951 and 1961 and by 15% between 1995 and 2012. The density of livestock increased from 50 animals per 100 hectares of grazing land in 1951–1952 to 154 in 2012. There are three major categories of livestock keepers in the arid zone of India:

- ***Labor pastoralists*** (the landless or near-landless who depend mainly on wage labor, but keep a few animals)
- ***Agro-pastoralists*** (large, small and marginal farmers who keep livestock as a secondary income-generating activity)
- ***Landless livestock specialists*** (people with little or no land but for which livestock production is the main livelihood activity)

In arid areas, the contribution of livestock is as high as 50% and goes up to two thirds of the farmers' total income during drought years. This value increases with a shift from subsistence agriculture to more open market economics, to include specialization and intensification of production systems. For landless livestock specialists, livestock may be the principal livelihood activity and source of income. However, these people are heavily dependent on common grazing resources including farmers' fields for grazing at certain times of the year (Pankaj et al. 2017). Agro-pastoralists, particularly small and marginal farmers, are relatively more dependent on livestock than large farmers. This means that for them, livestock are relatively more important as a source of planned income and as a buffer against poor crop yields. Large farmers are less dependent on common grazing resources, as they produce larger quantities of crop residue and also have access to large areas of private wasteland.

The farming system research that began in the early 1980s derived its tools from rich indigenous knowledge accumulated over the ages for resilience and amalgamated it with scientific innovation to achieve higher levels of production, while managing the fragile resource base. Owing to risky crop production, land is put to alternative uses with perennial components like agro-forestry, agri-horticulture, agri-pasture, horti-pasture, farm forestry, etc. (Table 15.2). A major part of Rajasthan is an arid region and there is inadequate availability of fodder and feed resources due to frequent drought and famines. Still, it ranks first in wool, second in per capita milk production and availability, and fourteenth in egg production in the country.

Impact of Livestock on Sustainable Agriculture

Owing to dryland technologies, except for wool production, all livestock product output has been increasing since 1995–1996 (Fig. 15.7). The impacts of livestock on the soil fall into two broad categories: firstly, the physical impact of the animal on the soil as it moves around and secondly the chemical and biological impacts of the feces and urine that the animal deposits on the soil. Physically damaged soil can be even more susceptible to the chemical and biological impacts of feces and urine. These factors are important in arid and semi-arid regions of India as livestock are dependent on common pool resources for grazing and getting nutrients (Pankaj et al. 2014). Heavy livestock such as cattle compact the soil structure and destroy vegetation on the parts of a field where they tread most often. This is visually appar-

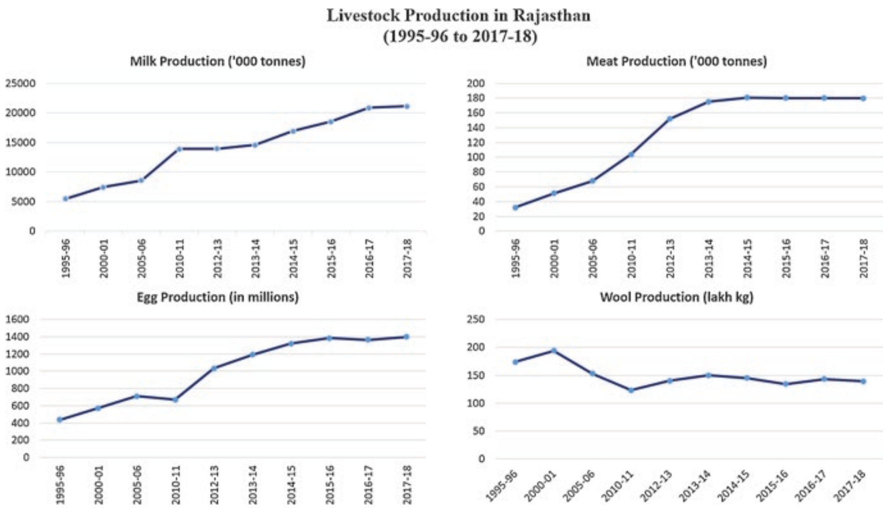


Fig. 15.7 Livestock production in Rajasthan state (Source: State-wise estimates of value of output from agriculture and allied activities with new base year 2004–2005 (published in 2013) (Source: Ministry of Statistics and Programme Implementation, Government of India)

ent around drinking water troughs, entrances to fields and other parts of the land where the animals congregate. Destruction of the soil structure in this way is known as ‘poaching’ and can be seen to be harmful because restoration of vegetation does not always occur spontaneously once the grazing animals are withdrawn. Sheath and Carlson (1998) found losses of 5–10 kg dry matter ha^{-1} d^{-1} where up to 50% of an area was affected by cattle treading but recovery occurred within a few months. Compacted soil becomes dense, making it difficult for new shoots to penetrate the soil and emerge; structureless soil is unlikely to drain well and will pond after moderate rainfall. Soil particles from these zones will be susceptible to erosion carrying particles, organic matter and phosphorus into surface waters (Warren et al. 1986). Anaerobic zones in waterlogged soils will encourage denitrification which implies a loss of nitrogen and pollution of the atmosphere with N_2O if conditions for denitrification are sub-optimal in the compacted zone. Problems with soil structure are not limited to cattle farming. Sheep grazing is largely extensive in upland rough grazing. On some farms, however, sheep are used to graze root cover crops (such as turnips) in the late winter and all but sandy soils are likely to be susceptible to damage. At equivalent (i.e. metabolic weight) stocking densities on wet soils, short-term treading by sheep is less damaging than treading by cattle (Betteridge et al. 1999).

Although many of the impacts of animal waste on the environment concern losses to water or the atmosphere, soil is an intermediary and as such these impacts deserve space here. The amount of urine delivered into the soil by a grazing cow is of the order of 2 litres applied to an area of about 0.4 m^2 (Addiscott et al. 1991). This represents an instantaneous application of 400–1200 kg N ha^{-1}. Such an amount burns vegetation and is often toxic to plant roots which cannot immediately recover to take up the N (full recovery can take up to 12 months and the problem is obviously worst in areas where animals congregate). Urea in soil is quickly hydrolyzed and given that grass can take up perhaps 400 kg N ha^{-1} annually without loss, pollution of groundwater or the atmosphere is almost inevitable whenever urine is applied to soil. Both calcium and magnesium are also lost in substantial amounts from urine patches on pasture soils (Early et al. 1998). Compaction of and damage to soil also limits the growth of pasture and the use it can make of the available nutrients. Douglas and Crawford (1998) found a reduction of between 1.7 and 2.1 t ha^{-1} in dry matter production in a compacted sward and a reduction in recovery of N from 71% to 55% of that applied to uncompacted and compacted swards, respectively.

The amounts of nutrients in manure are equally a source of waste, a missed opportunity and a potential pollutant. Manure is partly microbial in composition, derived from fermentation during digestion, and partly composed of recalcitrant components of the feed. As such it is rather less decomposable than fresh plant material and does not supply N to soil as rapidly or as damagingly as urine. It does, however, block light, and grass growth underneath manure will be temporarily retarded. Some regrowth occurs with penetration where the pasture is well enough established, some with reseeding directly into the manure.

Development of irrigation systems has impacted the number of cultivations as well as increasing the total cropped area (Fig. 15.8). However, livestock populations have not changed much over seven decades in the arid regions, although the inland drainage plain has seen significant changes in the region due to upscaling of watersheds.

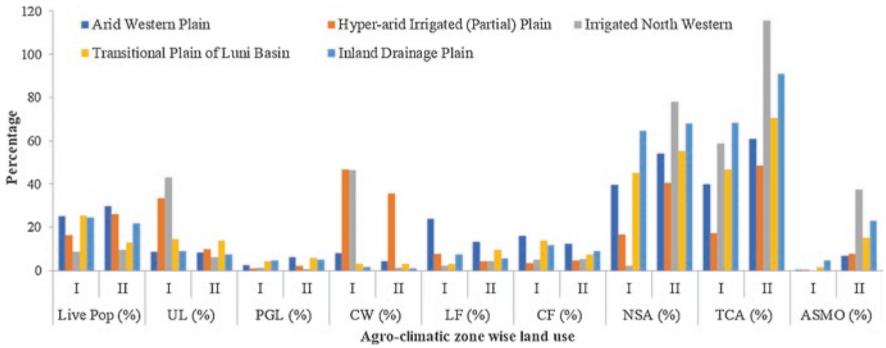


Fig. 15.8 Agro-climatic zone-wise land use and livestock population in the arid zone of Rajasthan. *Live Pop* livestock population, *UL* uncultivable land, *PGL* pasture and other grazing land, *CW* cultivable land, *LF* long fallow, *CF* current fallow, *NSA* net sown area, *TCA* total cropped area, *ASMO* area sown more than once, *I* 1956, *II* 2012 (Source: Animal Husbandry Department and District Statistical Handbooks, Government of Rajasthan)

Food and Nutritional Security in Arid and Semi-arid Regions

India's population of 1.3 billion is around 18% of the world population and is further estimated to reach 1.6 billion by 2030. Thus, Indian agriculture systems have a huge responsibility to ensure secure access to food and nutrition for every Indian citizen, now and in the future. FNS needs to be linked to various socio-economic factors for perfect implementation in arid and semi-arid regions of India.

Linking Poverty, Nutrition and Food Security for Sustainable Development

To estimate poverty in a region it is not only the household income level that is taken into consideration for determining the extent of poverty; also variables like consumption, expenditure and nutrition standards are included in estimation of poverty in the semi-arid tropics and arid regions. In a longitudinal study carried out in Andhra Pradesh and Maharashtra states, both located in the semi-arid tropics, it was inferred that on average the total consumption by a person in a rural household was 2135 calories containing 49 grams of protein; the recommended dietary standards are 2000 calories containing 50 grams of protein per head. More than 50% of households in these states are deficient in protein consumption rather than total calorie intake (Rao 2000). Protein intake may be correlated with the cultivable area of pulses in the region and Maharashtra has less acreage under pulses than Andhra Pradesh.

Any changes in population, income or technologies bring corresponding changes in poverty, inequality and food security. A World Bank Report (2015) acclaimed the efforts of the United Nations in achieving the Millennium Development Goals (MDGs) which significantly reduced global poverty from 12.7% in 2012 to 9.7% by 2015. There has been a significant reduction in poverty levels across most of the regions of the world except in sub-Sahara African countries where poverty seemed to increase from 350 million in 1990 to 60 million more in 2015. Among the South Asian countries, Sri Lanka, Bangladesh, China and India possessed the highest numbers, of undernourished populations, to the extent of 281 million, as per 2014–2016 estimates. Bangladesh achieved its MDG goal (MDG1: eradicating hunger), achieved mainly through its promising national food policy. India still has the second-highest undernourished population.

Drivers Promoting Food and Nutritional Security

Many international organizations, based on experiences of working with food security issues, have suggested four ways to reduce poverty, hunger and malnutrition among the rural poor in semi-arid areas. These include increasing economic growth (mostly referring to inclusive growth by involving poor, disadvantaged and marginal populations) and improving the resource productivity of small and marginal farm families. Because agriculture is a major occupation in rural areas that have the highest percentage of malnutrition, implementation of safety net programs and political stability in the region are called for (FAO, IFAD and WFP 2015).

Increasing economic growth is considered the best strategy to reduce poverty. However, economic growth should be inclusive in nature which implies embracing poor and marginal populations, including poor rural families, who need to be brought into the development pathway. They should be provided with the best possible opportunities to access resources, develop skills and improve incomes for livelihood development. The possibility and scope for achieving inclusive growth is high in agriculture where livelihoods for the majority of the rural population are derived from small holdings with scarce resources. The majority of the farmers with small holdings usually depend on their own land, labor and capital. Their inclusion is crucial to increase economic growth by adopting practices like diversification and intensification of farming.

Rural women constitute a major workforce contributing to the rural economy. However, by virtue of their roles and responsibilities for farms and families in the context of the social norms and culture of the society, they are being pushed into a secondary position in society. Given the extreme workload and long hours of work they remain withdrawn from policy and development activities. Inclusive growth, here, implies that rural women should be given recognition for their contribution to economic growth. It is necessary to provide a greater number of equal opportunities to develop skills, improve assets, enhance livelihoods and increase resilience at times of climate adversities.

Improving the productivity of resources of small landholdings has great scope for achieving food security. For instance, investment in infrastructure and institutions; improvement of institutional credit; timely supply of seed, fertilizers and pesticides; extension services; and ensuring a congenial environment for better farming and marketing constitute important sources for eradicating hunger and poverty.

Another significant, viable and important strategy proposed by governments, these days, is to sanction safety net schemes and social protection programs with the potential to promote adaptation. These are mostly found to be effective during occurrence of natural hazards (droughts or floods) when crops and livestock are severely affected. For example, in the semi-arid and arid areas of India the government introduced an employment guarantee act called the MGNREGA program to provide employment for 100 days per annum during lean periods to the rural poor, comprising laborers, wage earners, small farmers and women. Studies conducted on the impacts of MGNREGA indicated that the program enhanced equity and improved the resilience of small landholders and the downtrodden to withstand drought or any other natural calamity.

Gender Equality Implications in Agriculture for Achieving Food and Nutritional Security

In developing countries of the world, most women in rural households play a significant role in safeguarding the nutritional security of the family. In adverse conditions of drought, women feel the burden of fulfilling the task of feeding children and other family members. Women adopt varied strategies to reduce impacts of weather risk on both food production and meeting the food consumption needs of the family despite social constraints in access to resources and social norms. Decisions on selling of land, livestock and assets to withstand drought lie usually with men but selling of a small number of chickens, fruit and vegetables from the farmyard and often reduced food intake rest with women. Women's education levels and social status interact with social norms and the cultural context in a rural household also influences the extent of food intake within a family. Food and nutritional security issues vary with class, marital status and gender. For example, unmarried women and widowed women face differential and more severe impacts of climate change on food availability than married women, owing to the different dependency status and economic conditions. Women are totally dependent on the assets they own or can access and on prevailing economic conditions.

Gender equality in agriculture is expressed in terms of access to land, water and resources. Women play important roles as producers and provide relief to the most vulnerable for attaining FNS in rural areas. Women undertake the bulk of unpaid care work in rural households explains poor and uneven growth progress and they provide essential domestic services within households and to community members. However, despite decades of efforts to education, health and proper nutrition, all of which expand address gender inequalities, many rural women continue to and strengthen human potential. Removal of gender-based constraints that limit their access to social protection can establish a virtuous circle of progress, contribute to growth and take advantage of new opportunities. Involving the poor in efforts to improve livelihoods through increased income-generating opportunities such as employment can shape national economies for the better.

Institutionalization of Diversification and Land Use Management Practice Models for Food and Nutritional Security

Achieving global food security remains a key challenge for the future, particularly given continued population increases, dietary shifts, and global climate change. A focus on agricultural intensification as a mechanism for producing more has been a major means of achieving food security (Hazell and Wood 2008). Farmers in arid and semi-arid regions have adapted to climatic and other risks by diversifying their farming activities (Ebi 2011) and spreading the risk among different crop and livestock types (Antwi-Agyei et al. 2014) or by increasing the range of agricultural products for markets or subsistence (McCord et al. 2015).

Climate change and sustenance of food security are the main challenges of the twenty-first century. In arid and semi-arid areas, rainfed agriculture plays a significant role, contributing 40% of the food basket of the world. The majority of food crops are cultivated in rainfed areas. Rainfed agriculture is mainly affected by the availability of and access to water – a critical resource that directly impact land use, land cover and the livelihood patterns of the people in the region. Looking at the history of rainfed areas worldwide, huge shifts in land use and land cover changes are evident. The predominant changes range from grazing of sheep in rangelands to dominant irrigated intensive agriculture (Hole 2007). It is reiterated that these changes have been brought about by government policies, intensive bore (well) irrigation, subsidies for farm inputs, adoption of modern technologies such as use of fertilizers and pesticides, farm machinery, use of diesel pump sets, etc. Land use management practices are influenced by soil, climate and other factors like labor shortages, land ownership, and economic and political factors, which often impose constraints on higher productivity (Nuhu et al. 2007).

Intensive agricultural practices followed over a few decades have resulted in depletion of fertile soil, decreased groundwater levels and sparse vegetation on the ground, and farmers' preferences for getting quick returns have had negative impacts on livelihoods and foods security. The current climate manifestations resulting in temperature changes and occurrence of frequent droughts and floods have further impaired crop productivity, increasing hunger and poverty. Revamping farming to meet food security needs, eradicate hunger and alleviate poverty entails conserving natural resources while improving the productivity of rainfed agriculture in semi-arid areas in a sustainable manner (Nirmala et al. 2019).

Experts, scientists, policy makers, and learned experts from countries that focus on agriculture have taken steps (after realization of fallacious farm policies leading to food insecurity) and devised tools and methods to mitigate damage to the environment and the food needs of the country. Different models adopted and institutionalized in countries are discussed in this section to gain insights into the extent of diversification and various land use management practices that have been followed and also to gain firsthand knowledge of changing scenarios in semi-arid and arid regions of the world. Some successful models prevailing in countries of semi-arid and arid regions (SAR) are discussed here.

Integrated Farming System Development for Food Security and Livelihood Development in India

An integrated farming systems approach is multifunctional, contributing to food security and livelihood enhancement. Promotion of the IFS model particularly in the agriculture sector through effective combination of one or more enterprises with crop components such as livestock, poultry, ducks, fish, goats, mushrooms, or bees (depending on the availability of resources) and effective recycling of waste for sustainable natural resource development have been found to be more profitable and environmentally sustainable. In semi-arid areas, with a predominance of small and marginal farmers – who have limited finances and limited access to resources such as land, water, inputs, credit and technology – farmer are now being encouraged to adapt to the IFS model on a small scale to earn a decent income from each of the enterprises that is sufficient to meet livelihood needs. In India, farmers quite often face challenges of volatility of markets and climate variability impacts leading to loss of crops and income (Reddy et al. 2018). Integration of small-scale enterprises with a crop that involves low investment, more profit and only family labor is more appealing. According to National Sample Survey Organization (NSSO) data (2003), the output value per hectare was Rs. 14,754 for marginal farmers, Rs. 13,001 for small farmers, Rs. 10,655 for medium farmers and Rs. 8783 for large farmers. It could be inferred from the NSSO data that small farms can be operated more effectively in terms of income generation than large farms but due to paucity of resources, the small farm holders often suffer from social maladies such as poverty, malnutrition, unemployment and need for migration.

For example, in a study reported by a farm science centre in Chattisgarh state in India an IFS model practiced by a marginal farmer on 1.5 acres of land earned four times the net return gained from the traditional practice of monocropping, along with generating employment for 316 man-days per year instead of 165 man-days in the same area. Duck raising and backyard components contributed to nutritional security. Green fodder and straw that were produced were consumed by the milch cattle to produce more milk, earning more income for the farmers (Sujit et al. 2016).

The Farmer FIRST Approach in India

This is an approach that focuses on farmers, farmers' innovations, farmers' resources and knowledge, and science and technology – termed as 'FIRST'. It is a participatory approach integrating all components of a farm to develop the farm beyond productivity and profitability. The program was launched by ICAR as a frontline extension system in 2016. Local knowledge is dynamic and its use over a period leads to innovation and is key to sustainable development. This concept has driven the conception and operationalization of the Farmers FIRST project. It concentrates on all aspects of farms such as crops and cropping systems, natural resource development like soil and water, horticulture components, small farm mechanization and socio-economic aspects utilizing convergence and institutional linkages. The objectives and aims of the approach include strengthening the farmer–scientist interface (which otherwise is weak in the present extension system), technology assemblage with an emphasis on diversification (crops, livestock, horticulture, mechanization), and partnership and institutional development. The approach has adequately created an impact benefitting farm families to achieve nutritional security with inclusion of eggs in the diet with use of Srinidhi, a backyard poultry breed intervention.

Development of organized poultry has masked the contribution of backyard poultry or household poultry in rural areas of Telangana, a prominent semi-arid region of India where rural poultry constitute about 27% of the total poultry population. In order to improve nutrient availability to poor households in rural areas in the Vikarabad district, Telangana, low-input-technology backyard poultry farming using the Srinidhi breed was introduced under the Farmers FIRST project for supplementing the earnings of poor farmers and landless laborers. Srinidhi-variety birds (25 each) were given to 50 geo-tagged, pre-trained landless and small farmers from Pudugurthy village (17.18°N, 78.02°E), Pudur Mandal, Vikarabad District, Telangana, India, for rearing. For comparison, the performance of 100 birds of local varieties was monitored. The nutritional status pre- and post-intervention was assessed and, as per the production and reproduction performance data obtained from the Srinidhi poultry, their role in reducing the nutritional deficiency in the area was demonstrated to the farmers. At 20 weeks of age, the average body weight of the birds of local varieties was only 1.36 kg, whereas the Srinidhi variety, at the village level, achieved an average body weight of 2.35 kg, with survival rates of 60% and 80%, respectively. On an adult unit basis, the diet was deficient in energy as well as protein and it had energy levels only sufficient to meet their basal metabolic rate (BMR) requirements. After the intervention, as the farmers did not sell their produce to outsiders and used the produce for their home consumption only, the energy deficiency in the diet was reduced to 33.52% and the protein percentage in the diet exceeded the requirement by 13.21%. The diet chart revealed that females and children were more deficient in diet than males in both types of families. After the intervention, the dietary protein percentages were in surplus to the tune of 23.2, 6.8 and 76.7% in the males, females and children, respectively. The study revealed significantly higher production performances in the Srinidhi variety than in the indigenous poultry birds, providing a better support system for livelihoods and nutritional security under backyard poultry production in this dryland region (Pankaj et al. 2019a).

Sheep farming is the strength of South India (a major semi-arid region of India) where chevon is a preferred species for meat, but in some areas of Telangana, its farming has been discontinued due to forage unavailability. The rural masses are already suffering from food and nutritional deficiencies. In order to improve nutrient availability to poor households in rural areas of Telangana, low-input-technology sheep farming, coupled with improved forage production, has been introduced under the Farmers FIRST project for supplementing the earnings of poor farmers. Sheep of the Deccani and Nellore breeds (five females and one male) were given to each of six geo-tagged, pre-trained small farmers from Gangupalle village (17.30°N, 77.98°E), Pudur Mandal, Vikarabad District, Telangana, India, for rearing. For comparison, the performance of 14 non descript goats was also monitored. The nutritional status pre- and post-intervention was assessed and, of the revenue generated from selling the sheep, 50% of the money was allocated for egg, chicken and chevon purchases for family consumption. On an adult unit basis, the diet was deficient in energy as well as protein and it had too low energy levels to meet BMR requirements. After the intervention, the energy deficiency in the diet was eliminated to meet BMR requirements in all categories of people in the family. The diet chart revealed that females and children were more deficient in diet than males in a typical family of six people. After the intervention, the diet included surplus protein to the tune of 14.27, 3.73 and 63.02% in the males, females and children, respectively. The study revealed significantly higher production performances of the indigenous breed (76.4% higher body weight) than the nondescript goats, with a better support system for livelihood and nutritional security in this dryland region (Pankaj et al. 2019b).

Strategies for Achieving Food and Nutritional Security in Arid and Semi-arid Regions

The following strategies should be considered to achieve FNS in arid and semi-arid regions of India:

- Increasing institutional credit and irrigated areas.
- Improving the marketing infrastructure and revitalizing the agricultural extension system.
- Ensuring that agricultural inputs such as seeds and pesticides are of appropriate quality.
- Ensuring that in the arid zone, agriculture is horticulture and livestock driven. The semi-arid zone also requires horticulture and livestock farming, but an annual crop can also be grown during the three months of the year when there is more water.

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Chapter 16
Vulnerability of Resource-Poor Farmers to Climate Change and Traditional Adaptation Pattern at High-Altitude Cold Arid Region

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Context and Setting

The agriculture sector plays a key role in Ladakh economy[1] and cropping with harvested glacier water in the lap of the Himalayas has developed as a small-scale farming system, well adapted to this unique and extreme environment with average annual rainfall of 103 mm. The majority of resource-poor farmers who inhabit deep valleys and river banks are highly exposed to on going climate change. Communities living in this high-altitude desert do not have access to a wide range of natural resources but live happily despite the harsh environment. The combined effect of diminishing snowfall and shorter-warmer winters has been impacting the glaciers resulting in shrinkages (accelerated glacial retreat). Consequently, farmers no longer get sufficient snowmelt water in the early summer when they need it for the pre-sowing irrigation. Premature snowfall enhances the land degradation of frost-heaved *Kobresia* dominated high-altitude pastures, impacting negatively on native biodiversity through allelopathic effects of *Cirsium arvense* – one of the world's worst weedy species. Generally flocks graze upon sites that are desiccated frost heave areas and most susceptible to colonization by aggressive invasive weedy plans. Hence retreat of shrunk glaciers has impacted the migration cycle of nomads in highlands confined to 27 deep valleys from Chiyu (January) to Dirigayao and

[1] Ladakh is the highest altitude plateau region in India (much of it being over 3000 m), incorporating parts of the Himalayan and Karakoram mountain ranges and the upper Indus River valley.

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Lama Bum valley (December). This pattern of grazing gradually not only decreases the annual grass cover but also affects perennial grass species adversely. Inadequate education, lack of access to resources (land, high-cost labour, etc.), poor local institutional capacity and services and gender were the key factors that shape vulnerability.

Any change in climate over time, whether due to natural variability or as a result of human activity, is known as *climate change*. *Vulnerability* to climate change is the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity and its adaptive capacity (Hasnain, 2012). Or, *vulnerability* describes the characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard. A disaster occurs when hazards and vulnerability meet. There are many aspects of vulnerability, arising from various physical, social, economic and environmental factors. Vulnerability reveals a number of underlying causes (poverty, limited access to power structures, resources, ideologies, economic systems, age, sex, illness and disabilities), dynamic pressures (lack of local institutions, education, training, appropriate skills, local investments, local markets, services, press freedom, macro-forces, population expansion, urbanisation, environment degradation) and unsafe conditions (fragile, physical environment, dangerous locations, dangerous buildings, etc., fragile local economy, low levels of income, livelihoods at risk and public actions). A hazard is a dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption or environmental damage. When this meets with hazards, disaster occurs (WHO/EHA 1998), and it is evaluated (Table 16.1).

There are different indicators of vulnerability (WHO/EHA 1998):

1. Physical: geography, environment, infrastructure, hazardous industries, etc.
2. Emergency management: plans, equipment, trained people, etc.
3. Demographic: numbers, density, structure, minorities, etc.
4. Health: patterns of disease and services, disabilities, etc.
5. Economic: income, production and productivity, insurances, employment, etc.
6. Communications: public education, information and warning systems, media, etc.
7. Psychological: experience, stress, acceptance, bravado, etc.
8. Societal/cultural: coping strategies, cohesion, language, leaders, beliefs, etc.
9. Organisational: Government and NGO services, logistics, policies, laws, etc.

Adaptive capacity: the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages and to take advantage of opportunities or to cope with the consequences. *Resilience* is the ability of a community to resist, absorb and recover from the effects of hazards in a timely and efficient manner, preserving or restoring its essential basic structures, functions and identity.

Table 16.1 Vulnerability evaluation (WHO/EHA 1998)

	Principal vulnerable elements	
	Tangibles	Intangibles
Floods	Everything located in flood plains or tsunami areas. Crops, livestock, machinery, equipment, infrastructure. Weak buildings	Social cohesion, community structures, cohesion, cultural artefacts
Earthquake	Weak buildings and their occupants. Machinery and equipment, infrastructure. Livestock. Contents of weak buildings	Social cohesion, community structures, cohesion, cultural artefacts
Volcanic eruption	Anything close to volcano. Crops, livestock, people, combustible roofs, water supply	Social cohesion, community structures, cohesion, cultural artefacts
Land instability	Anything located on or at base of steep slopes or cliff tops, roads and infrastructure, buildings on shallow foundations	Social cohesion, community structures, cohesion, cultural artefacts
Drought/ desertification	Crops and livestock. Agricultural livelihoods. Peoples' health	Disruption of populations. Destruction of the environment. Cultural losses
Technological disasters	Lives and health of those involved or in the vicinity. Buildings, equipment, infrastructure, crops and livestock	Destruction of the environment. Cultural losses. Possible population disruption

Geography and Climate

Ladakh is situated north of the greater Himalayan mountainous range with three parallel ranges of the Himalayas, the Zanskar, the Ladakh and the Karakoram. Between these ranges, the Shayok, Indus and Zanskar rivers flow and most of the population lives in valleys of these rivers running parallel from the south-east to north-west. It lies between 75^0 15′ E to 80^0 15′ E and 32^0 15'N to 36^0 00' N and altitude ranging from 2300 to 5000 masl. It has a cold desert climate (Köppen climate classification, BWk) with long, harsh winters from October to early March, with the temperature range from −28 °C in winter to 33 °C in summer. This region receives occasional snowfall during winter. Region experiences mean annual precipitation of 80–300 mm, which is scanty and negligible in the thirsty laps of mountains. The region constitutes the western part of the Tibetan Plateau and forms the main cold desert region in India. Politically, Ladakh forms one of the three geographically and culturally distinct regions in the Indian state of Jammu and Kashmir, bordering China/Tibet to the east and Pakistan to the north. This region makes for over 60% of the state in terms of area and a mere 2% in terms of population. At around three persons per square kilometre, it is likely the most sparsely populated region in an otherwise densely populated country.

There are significant variations in climate within the region. Much of the Nubra, Sham and Suru valleys are at lower elevations of 2800–3500 metres above sea level and experience a shorter and less harsh winter and taking two short-duration crops in the relatively longer summers. The Changthang region, vast plains forming eastern Ladakh, on the other hand, where villages are located between 4500–5000 metres above sea level, experience 7–8 months of winter with temperatures dropping down to –45 °C(Fig. 16.1). The people here are largely pastoralists and are able to practice

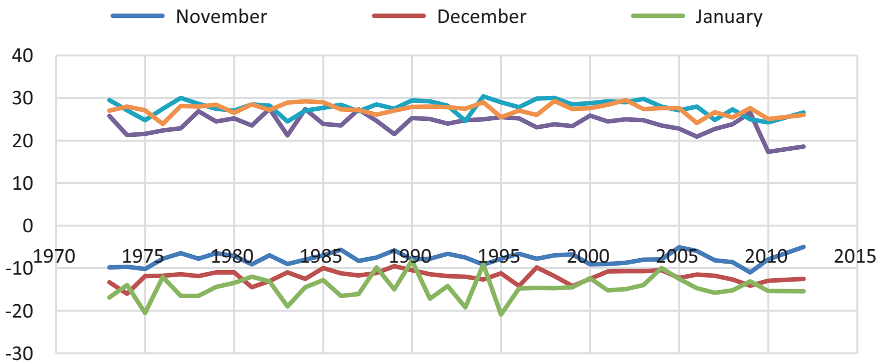


Fig. 16.1 Minimum and maximum temperature (°C)

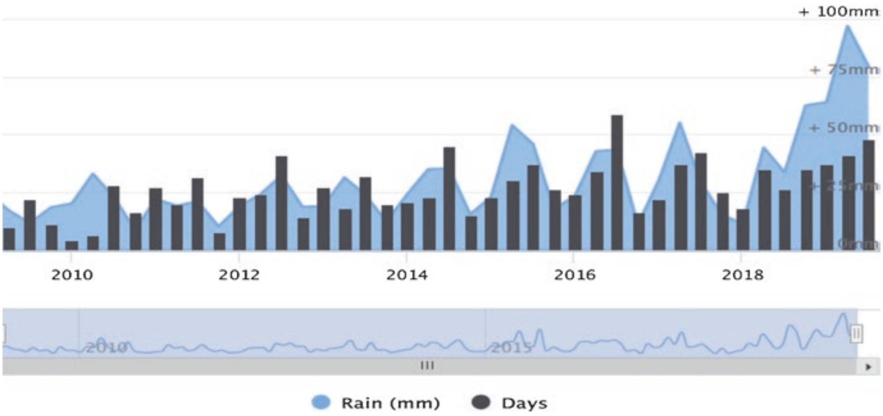


Fig. 16.2 Average rainfall and rainy days

limited or no farming. Majority of the villages in the region, however, are located at 1000–1500 metres and experience winter temperatures of –15 °C to –30 °C (Hasnain 2012). Precipitation over Leh falls mostly during the monsoon period with the extreme precipitating event (cloudbursts) also occurred during 2010. During winter and pre-monsoon also, there is significant precipitation over Leh due to the influence of western disturbances (Fig. 16.2). But on an average, the daily precipitation amounts range from 0.5 to 1.5 mm/day. These conditions define the climate of the Leh region as cold and arid (dry) (Chevuturi *et al.*, 2016).

Himalayan Glaciers: An Overview

The Himalayas, the youngest and one of the most fragile mountain systems in the world, derive their name from a Sanskrit word which means ‘abode of snow’. The glaciers of the Indian Himalayas are spread over different river basins including the Indus, Ganga and Brahmaputra (Shang et al. 2020).

Receding Glaciers Impacting Natural Balance

General concepts of vulnerability and adaptive capacity in context with climate change are required to be understood if they are to be useful at the scale of the communities and regions where people live. The varied global environmental challenges pose hazardous implications for natural ecosystems and cultural resources, loss of biodiversity, climate change, land degradation, etc. and the health in Ladakh regions. Gradual shift of the snowline due to progressive increase in atmospheric air temperature and release of the water from snow and ice melting makes the water level constant in the rivers (WWF 2005). The Himalayas – where the danger of catastrophic flooding is severe – and glacier-fed rivers supply water to one third of the world's population, and the vast majority of all Himalayan glaciers have been retreating and thinning over the past 30 years, with accelerated losses in the last decade. The Himalayan glaciers that feed seven of the great rivers of Asia (the Ganga, Indus, Brahmaputra, Salween, Mekong, Yangtze and Huang He) and ensure a year-round water supply to two billion people are retreating at a startlingly fast rate (WWF 2008). Recent studies from 466 glaciers of the Indian Himalayas indicate that there has been a 21% reduction in the glacierised area – from 2077 sq. km in 1962–1628 sq. km in 2004 (Kulkarni et al. 2007). Smaller glaciers of less than one sq. km have reduced in area by as much as 38% compared to a 12% retreat of the larger glaciers (Kumar et al. 2009). Exploitation of natural resources associated with growing population has led to increasing pollution, declining water quality, land degradation, etc. Extreme climate events including flooding, heavy rainfall, droughts, heat wave and cold stream, etc. are also the consequences of climate change in Nepal.

Growth of Farming

Agriculture is the main occupation of the rural people of the district. The people of Ladakh have developed a small-scale farming system adapted to this unique and extreme environment with 9824 hectares of cultivable lands with potential pastures. Traditionally, families rely essentially and more on subsistence agriculture based on barley and wheat that constitute the main crops as well as on rearing of livestock such as yaks, dzos, cows, sheep and goats. Wheat, pulses, oil seeds and other crops (e.g. millets) are also grown. The other major crop is fodder, particularly alfalfa. Under horticulture, apple and apricot are major fruit crops. Forest occupies an estimated area of 29.00 sq. km in the district. Traditional agroforestry with *Poplars and Willows,* crop/animal systems are very common.

Families are usually self-subsistent, each household producing its own cereals, fodder, vegetables, butter, milk and handicrafts. During the short summer season, the main activities are agricultural work and dung collection for winter heating, whereas few activities are undergone during winter due to the harsh conditions. Following are some of the potential and sustainable livelihood agricultural opportunities in winter season for Leh – Ladakh region.

Methods: Indicators and Sources of Data

The areas under study were pilot village and hot-spot Chushot, Nubra region, Changthang alpine meadows, land use systems, etc. i.e., micro-level monitoring system, covering possible indicators. This task covers areas of study, *viz.* crop production parameters, agroforestry, fisheries, camel and yak rearing. It was an exploratory study to measure density and diversity within plant communities and adaptability of local land users and identify the constraints to achieving sustainable land management. Interventions are comprised of (i) augmenting input supply, (ii) improving resource management for sustainable agriculture and (iiis) strengthening research-farmer interface. An assessment of vulnerability was carried out in 12 villages of cold arid regions of Leh, Ladakh, and Nubra valley. Based on physical, vegetation and socio-economic parameters, villages have been grouped under three situations: (1) mountainous terrain with deep to very deep valleys at higher altitudes between 3590 m and 3897 m above MSL (Umla, Saboo, Stakmo and Nang), (2) the central rocky uplands with raised flood plains of river Indus having rock/boulder-gravel-sand filled surface at moderate altitudes between 3146 m and 3270 m MSL (Nimoo, Rambirpore, Stakna and Chushot) and two villages (Phey and Spituk) located on a gentle lower flood plain of Indus river at a lower elevation of about 3200 m above MSL. Khardung and Hunder are the two other villages located within the Nubra valley. In addition, other altitudinal places like Changthang and Nubra were considered in the studies for variation in climatic variability.

Distributional Limits of Flora and Fauna

Warming in the Himalayas is predicted to increase upper distributional limits of some plant species and so more vegetation cover may be expected and a greater abundance of species adapted to warmer climate. This hypothesis was explored by revisiting uppermost plant populations after 10 years (2003–2013) and doing detailed monitoring of vegetation changes in permanent plots (2009–2012) and age analysis of plants growing from 5500 to 6150 m. Plant traits and microclimate variables were recorded to explain observed vegetation changes. The elevation limits of several species shifted up to 6150 m, about 150 vertical metres above the limit of continuous plant distribution (Dolezal et al. 2016). Still, a relatively large and potentially colonisable area is found above the current upper distributional limit of vascular plants within this region.

In Ladakh, it has been observed that distribution and adaptation of new fruit varieties have been recorded due to rise in mean temperatures in Ladakh by 1.7 °C during the last century and the warming accelerated in the 1990s (Bhutyani et. al. 2007). On the other side of the coin, farmers from Nubra and Leh have seen the positive effects of climate change. Now it is possible to grow several crops and vegetables in Ladakh, which was impossible earlier. Farmers nowadays grow capsicum, cucumber, cauliflower, tomatoes, okra and even watermelon. "Rise in temperature has made this possible here" (Joshi 2018). Several farmers in Nubra valley and other parts of Ladakh also testify to this. "We had limited options to grow crops like potatoes, turnip, peas, radish and a few more vegetables", said 44-year-old Gulam Qadir. "Now the situation has changed". Chewang Norphel, Hussain has grown several vegetables and fruits in his garden in Leh, says, "The negative impact is huge on farmers but the positive (effect) is that now you can find more than 40–50 species of vegetables here and side by side you can grow many fruits. You know during earlier days the fruit trees could be grown only up to Leh. Now we can grow this fruit trees even 70 km up from Leh".

Fish Distribution of Ladakh region According to altitudinal ranges of habitat (DCFR 2017), there have been 20 indigenous as well as exotic fish species (spp.) revealed belonging to 12 genera (*Schizothorax, Schizothoraichthys, Schizopygopsis, Diptychus, Ptychobarbus, Crossocheilus, Cyprinus* spp., *Nemacheilus, Triplophysa, Glyptosternum, Oncorhynchus* and *Salmo*) and 4 families (Cyprinidae, Nemacheilidae, Sisoridae and Salmonidae) which are reported from river Indus at different sampling sites during June–July, 2016. In Zanskar, fewer fish species (ten species) have been reported than Shyok and Indus rivers, species belonging to nine genera (*Schizothorax, Schizothoraichthys, Schizopygopsis, Diptychus, Ptychobarbus, Crossocheilus, Cyprinus* spp., *Triplophysa* and *Glyptosternum*) and three families (Cyprinidae, Nemacheilidae and Sisoridae). The five genera (*Schizothorax, Schizothoraichthys, Schizopygopsis, Diptychus* and *Triplophysa*) have been recorded and seven species under two families (Cyprinidae and Nemacheilidae) and one order (Cypriniformes) from Shyok River during study time. Still, a relatively large and potentially colonisable area is found above the current upper distributional limit of vascular plants within this region.

Accelerated action of frost heaving, erosion, vegetal degradation, salinisation, human activities, where generally flocks graze upon sites, have resulted into desiccated frost heave and are most susceptible to colonization by aggressive invasive weedy plans. Premature snowfall enhances the land degradation of frost-heaved *Kobresia*-dominated high-altitude pastures, impacting negatively on native biodiversity through allelopathic effects of *Cirsium arvense* – world's worst weedy species. Under the regular influence of climate change, processes involved in degradation such as have accelerated to many folds (Fig. 16.3).

State of Ecosystem Health in the Cold Desert of Indian Himalayan Region

The Ladakh region in the south of the Karakorum Range is unique with its cold arid climate and vast barren landscape. People in this region subsist on scarce natural resources. Even small changes in climate of the region could bring hardship to the people (Chevuturi et al. 2016).

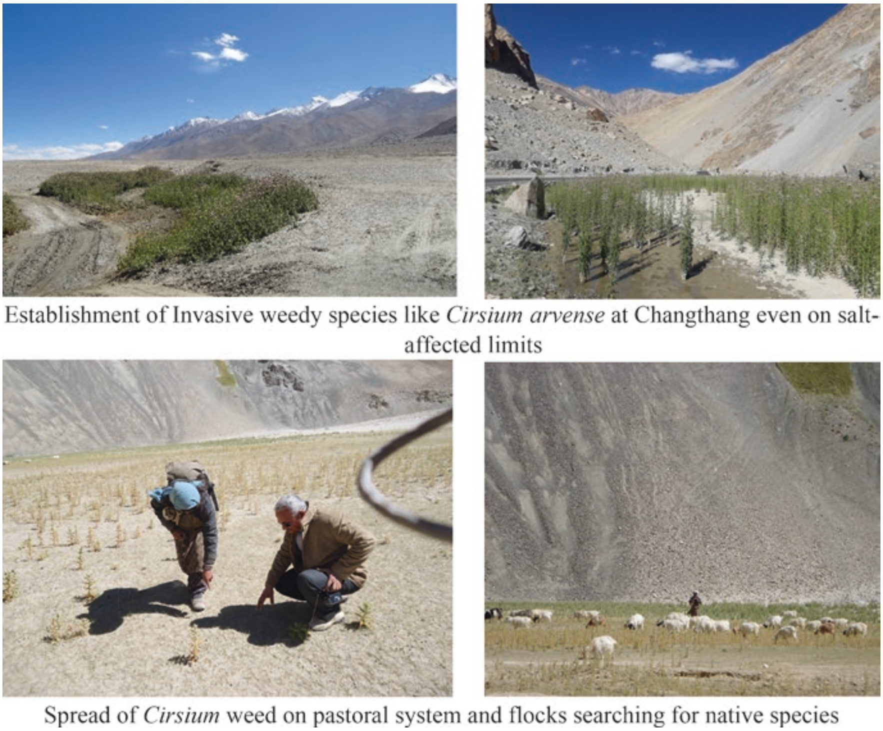


Fig. 16.3 *Cirsium* infestation and its distributional limits to Changthang

Ecosystem security has been an issue of worldwide concern for many decades, whereas issues of food security and its specifics in high mountain regions were often neglected. In the cold arid environment like Trans-Himalayas where mountain agriculture, is still the dominant land use and importance of subsistence base for staple foods, is also focused in current consumption patterns. Therefore, ensuring agriculture sustainability for the well-being of peoples of cold region and their long-term sustenance is critical not only for ensuring food security for mountain people but also in the larger context of conserving the biodiversity under varied land use systems. But people are finding new avenues of employments like tourism, army and government jobs and booming construction activities. Nonetheless traditional farming practices dominate, often associated with reduction in crop productivity by 60–70 per cent due to lack of organic matter in the soil and invasive plants like *Cirsium* (30–40 per cent pressure). The major emphasis on cash crop (vegetable production), accompanied by increased incidence of insect pests and diseases (5–10 percent), reduced cultivated area (9824 ha) and high-cost labour in a changing climate.

At present public distribution system (PDS) has led to a lack of interest in cultivation of barley/wheat cultivation. There has been a shift generally to growing alfalfa fodder, because it is a high value crop that regenerates automatically in the next season. The shortage of fuel wood and the high price of imported conventional fuels result in a situation of high energy vulnerability.

Uplands are home to some of the world's most threatened and endemic species, and little is known in detail about the vulnerability of mountain ecosystems to climate change. Intuitively it seems plausible that these regions, where small changes in temperature can turn ice and snow to water and where extreme slopes lead to rapid changes in climatic zones over small distances, will show marked impacts in terms of biodiversity, water availability, agriculture and hazards and that this will have an impact on general human well-being (Sharma et al. 2009). Preliminary studies indicate that the Himalayas seems to be warming more than the global average rate (Liu and Chen 2000; Shrestha et al. 1999), temperature increases are greater during the winter and autumn than during the summer, and the increases are larger at higher altitudes (Liu and Chen 2000). It was reported that the average temperature of Kashmir valley has gone up by 1.45 °C over the last two decades (Sinha 2007). A rising snow line is expected to shift the species distribution to higher elevations. The atmospheric temperature generally drops by 1.5 °C for every 300 m elevation, and therefore, with an average 1 °C rise in temperature, most species are likely to extend their distribution upwards by 300 m; another effect of rise of temperature will be through an increase in water temperature and consequently lower availability of dissolved oxygen which may affect number of species both vertebrates and invertebrates.

Vast cold water resources across Indian uplands present a wide range of altitude and water temperature and support 258 fish species belonging to 21 families and 76 genera (Vass and Gopakumar 2002 and Vass 2005). Fish distribution of Ladakh region according to altitudinal ranges of habitat (DCFR 2017) revealed 20 indigenous as well as exotic fish species (spp.) belonging to 12 genera (*Schizothorax, Schizothoraichthys, Schizopygopsis, Diptychus, Ptychobarbus, Crossocheilus, Cyprinus spp., Nemacheilus, Triplophysa, Glyptosternum, Oncorhynchus* and *Salmo*) and 4 families (Cyprinidae, Nemacheilidae, Sisoridae and Salmonidae) reported from river Indus at different sampling sites during June–July, 2016. In Zanskar (ten species) have been reported fewest fish species than Shyok and Indus rivers. Species belonging nine genera (*Schizothorax, Schizothoraichthys, Schizopygopsis, Diptychus, Ptychobarbus, Crossocheilus, Cyprinus* spp., *Triplophysa* and *Glyptosternum*) and three families (Cyprinidae, Nemacheilidae and Sisoridae). The five genera (*Schizothorax, Schizothoraichthys, Schizopygopsis, Diptychus* and *Triplophysa*) have been recorded seven species under the two families (Cyprinidae and Nemacheilidae) and one order (Cypriniformes) from Shyok River during study period. Still, a relatively large and potentially colonisable area is found above the current upper distributional limit of vascular plants within this region.

Many plants and animals have adapted to different types of aquatic habitats. Fish habitat is influenced by quality of the water as the special abiotic features, which includes its clarity, temperature, pH, oxygen content, alkalinity, pollution level, rate of flow, etc. Aquatic ecosystems may be classified as being (i) stagnant ecosystems, (ii) lacustrine and (iii) running water ecosystems. Water resources significantly support the aquatic biodiversity and play an important role in the sustainability of aquatic ecosystem. Therefore, to sustain the biodiversity of fish in river, sustainable management both of habitats and system of exploitation is required.

Fish is one of the most important components of any aquatic system which indicates the habitat suitability and general health of water body. The presence or absence of fish depends on the conducive aquatic environment and abundance of natural food in the form of plankton, periphyton and other micro- and macro-organisms. Moreover, the nutrients provide the baseline for the productivity of these aquatic water bodies which supports the existence and abundance of ichthyofauna. Suitable spawning ground, shelters and feeding ground play important role in the life cycle of fish and consequently in the sustainability of fish population. The migration and feeding at different stages of life cycle require specific habitat requirements and environmental condition. The river basin provides support in terms of fulfilment of suitable habit requirement, availability of food and favourable environment for spawning in the forms of shallow pools, primary productivity and flow pattern.

The species such as trout and other upland fishes are adapted to threshold of lower temperature regimes. A rise in temperature by even 1 or 2 °C is likely to affect their growth, physiology, reproduction and behaviour and consequently the distribution pattern. The changes in hydrological regimes and timing of flow variations will alter the habitat characteristics and available habitat. The composition of the aquatic flora and fauna and practically all ecosystem processes are determined primarily and largely by hydrological regimes, and even small changes in any one component of hydrology can affect one or more phases of life cycle of aquatic organisms.

Climate Change in Ladakh Hits Agriculture

Ladakh is a cold desert, which makes farming difficult due to its arid climate. It leaves farmers with limited options, and over that receding glaciers and frequent rains due to global warming, the changes in climate have started impacting farming patterns in Ladakh region of cold desert. Farmers have witnessed the growing water scarcity due to exhausted water resources and affected the health of rivers and water streams, thereby impacting the crop growth. The water scarcity is being felt in every village associated with glaciers which were earlier all covered by snow have melted. It is thought that the problem would increase in the coming years. There was 50% to 80% deficit in annual precipitation in Ladakh between 2013 and 2017, and 2016 was a year of record low rain. Almost 90% of farmers in Ladakh are dependent on snowmelt water, diverted for irrigation but not on rainfall pattern. There has already been an increase from 1.4 to 3 degree Celsius rise in average temperature of Ladakh in the past four decades. This has caused less snowfall and faster snowmelt in the higher regions. As a result of which, production of some crops declined by 30% to 50% in the past few years. Crops such as potato, barley, turnip, radish and peas have suffered due to non-availability of water. In addition, growing of even grass as fodder for livestock has also become very difficult as animal husbandry is second prime option of livelihood after agriculture.

Overall impact of climate change in western Himalayas, the glacier cover is melting faster, reducing it by almost 20% in these higher regions. Farmer Chewang Norphel is combating the water problem by creating artificial glaciers. His technique is simple-divert the water stream and slow down its speed during the winters so that it would freeze due to low temperature. This ingenious way helps to conserve water as ice in the form of an artificial glacier. During spring, the ice starts melting and water is available for irrigation. Many farmers in different villages of Ladakh replicate this experiment. Saving water is another way of conserving water and reducing its consumption for dry toilets but covering with human excreta by soils, turning it in the form of manure to be used in fields (Joshi 2018).

Wetlands

Wular Lake, Dal Lake, Manasbal Lake, Pangong Tso Lake, Tso Somiri Lake, Mansar Lake and Surinsar Lake are important lakes of the state with total water spread area mapped of 154245.4 ha against 0.40 lakh hectares of area reported in Economic Survey, J&K 2013–14. Ahmed and Ahmed, 2013 reported that the ecology of lakes of the Kashmir valley has been deteriorated drastically due to deforestation, silt deposition, disposal of sewage and domestic wastes and use of pesticides and insecticide in the catchment area. Ranjit Sagar is major reservoir with estimated water spread area of 4087.3 ha (Table 16.2), while Table 16.3 reveals the water quality parameters of upland rivers of Ladakh division of Indus River at four sites.

Table 16.2 Major wetlands area of Jammu and Kashmir, India

Sl. No.	Wetlands	Area (Ha)
1	Dal Lake	1342.6
2	Wular Lake	1282.4
3	Manasbal Lake	207.4
4	Anchar Lake	35.6
5	Vishansar Lake	46.0
6	Sheshnag Lake	53.6
7	Gangabal Lake	7.9
9	Pangong Tso Lake	30342.9
10	Tso Mori Lake	15103.5
11	Marsar Lake	41.8
12	Gadsar Lake	4.1
13	Kounsarnag (Konsar Nag) Lake	139.6
14	Ranjit Sagar	4087.3
15	Others	105638.6
	Total	158333.3

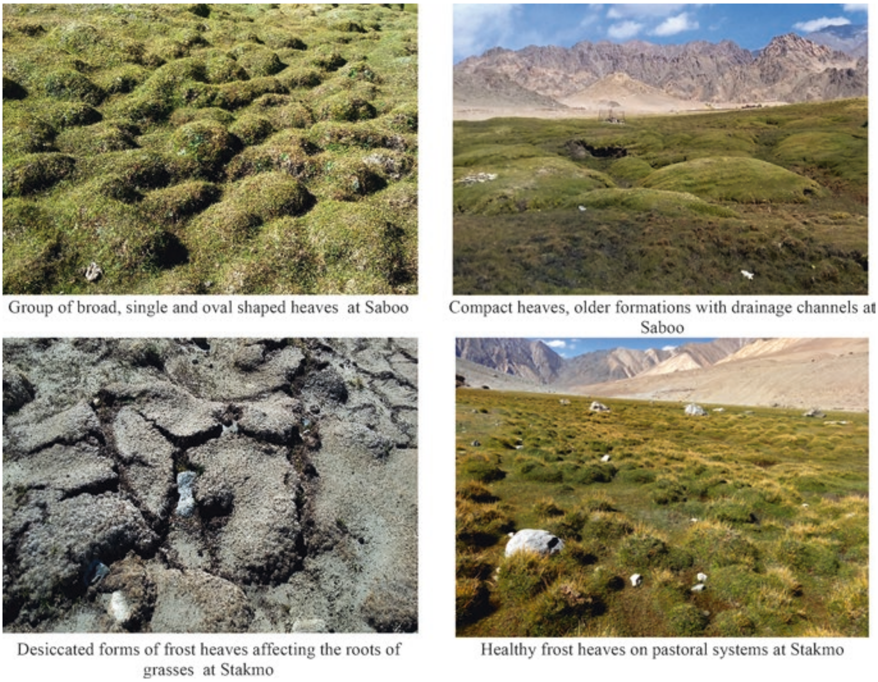
Table 16.3 Water quality parameters of upland rivers of Ladakh division (DCFR 2017)

Sites	Long (° E) Lat (° N)	Air temperature (°C)	Water temperature (°C)	pH	Dissolved oxygen (mg/l)	Total dissolved solid (TDS) (ppm)	Conductivity (μS/cm)
	Indus River						
1	77° 37′ 47.0″E 34° 04′ 11.0″N	28.3	15.5	8.34	9.25	111.3	222.4
2	77° 49′ 10.0″E 33° 49′ 45.0″N	28.2	14.9	7.99	9.52	108.4	215.9
3	78° 08′ 08.7″E 33° 28′ 38.5″N	28.2	14.2	7.82	9.75	107.9	213.5
4	77° 20′ 02.4″E 34° 09′ 42.1″N	27.1	13.1	8.10	10.1	102.1	205.1
Average		27.95 ± 0.56	14.42 ± 1.03	8.06 ± 0.21	9.65 ± 0.36	107.4 ± 3.85	214.2 ± 7.15

Effect of Frost Heaves on Pasture Ecology under Climate Change

The cold soils present a special challenge to land use managers owing to the effects of frost heave. In Changthang plateau, nomads raise yaks, sheep, and cattle, but due to overgrazing there is degradation of pasturelands. These wetlands or Changthang have extended into marshy meadow, supporting number of livestock during crucial winter months, and this specific ecosystem offers a large diversity of flora. Grazing pressure reduces the vegetation cover, and once the organic layers or the surface vegetation covers are disturbed or destroyed, the quality of the land deteriorates owing to susceptible topsoil erosion from which frost heaving originates due to glacial melt water flowing lower layers in the soil below the freezing line in the soil from a groundwater source.

A survey was carried out on the occurrence, types and use of frost heaves at various land use systems of cold arid region and assessed under climate change. Frost heaves are typical landforms that are associated with cold climates and are best known as wintertime uplift of the ground (Fig. 16.4). A common feature is their systematic growth under marshy, swampy, or at places with abundant surface or subsurface water flow. The dominant use of these lands is the grazing. Under wetland conditions, these surfaces act as excellent grazing lands, and under dry and desiccated conditions, the topsoil of the landform turns amorphous and degraded



Group of broad, single and oval shaped heaves at Saboo

Compact heaves, older formations with drainage channels at Saboo

Desiccated forms of frost heaves affecting the roots of grasses at Stakmo

Healthy frost heaves on pastoral systems at Stakmo

Fig. 16.4 Frost heaving and pastoral degradation

with no grass or vegetation. The survey found two dominant patterns of their formation; single or complex. The shape may be rounded, elongated or massive. In a spring site and under a pastoral or grazing land use system at Saboo, the clustered and massive frost heaves were 5 m long, 0.8 m wide and 1 m high, while the small and single formations measured 0.35 m long, 0.3 m wide and 10 cm high. The narrow and elongated heaves measured 1.8 m long and 18 cm high. At Stakmo, under boulder-filled surfaces, the heaves were 0.8 m long, 20 cm high but their circumference was maximum 2.2 m. Typical vegetation associated are *Kobresia, Astragalus, Glaux* spp., *Taraxacum* spp., and *Cirsium arvense, Carex* spp. It was also noted that *Cirsium arvense* – the invasive weed – is capturing the frost heaves mount and reducing the possibility of preferred flora from heaves. The samples of heaves affected by salinity have been sent for analysis.

Renewable Energy Measures

Many of the energy systems being implemented by LREDA (Ladakh Renewable Energy Development Agency) require the adaptation of technologies to suit the extremes of environmental conditions in which they will operate. Renewable energy

Fig. 16.5 Crop cafeteria for testing new crops at high altitudinal village Stakmo

projects in Ladakh range from making incremental changes to existing technology (e.g. modification of traditional water mills for pico-hydro schemes) to the introduction of completely new technologies (e.g. solar wind hybrid systems). Some of the important ways for better adaptations in Ladakh region during harsh winter are winter toilet (compost toilets); *bukharies* based on firewood; dried cowdung and kerosene; clothing like *gonchha*; using traditional knowledge of drying leafy vegetables for winter; storing vegetables in *Sudong* (pit)/*Sudbang* (storage underground room) during winter; polyhouses as protected structures; food like butter tea, kahwa, thukpa and noodles; traditional Ladakhi houses; etc.

Evaluation of New Crops and Cultivars in Stakmo Village

Crop diversification and introduction on new crop/varieties is important to overcome the effect of climate change. At Stakmo village, 36 new introduced crops and their cultivars were demonstrated. Amongst different crops, cultivars, barley, wheat, chickpea, and mustard, performed well in Stakmo – a deep valley village (Fig. 16.5).

Farmers' Perception of Climate Variability and Trends

In the high-altitude cold desert region of Ladakh, snowmelt from the glaciers, brought down by the numerous streams feeding the few rivers flowing through the region, are the only source of water, both for drinking and irrigation. Falling in the rain shadow of the Himalayas that do not receive the monsoon showers on which much of India depends, and being one of the driest inhabited places in India, rainwater is of limited utility to the farming communities here. Farmers of all villages also report similar changing trends and the erratic nature of rainfalls. Most importantly, people across the region are very concerned with the extreme forms that the rains have often taken in the recent years, with cloud bursts and flash floods seemingly establishing a pattern of regular occurrence in the region and wreaking havoc on their lives (Hasnain 2012), and these disasters continue to erode the man-made cultivated soils, took years to evolve, being eroded through flash floods and farmers suffers the consequences. Ladakh, located at high altitudes at a height of more than 3000 metres above sea level, sometimes leads to acute health problems, manifested as headache, vomiting, breathlessness, sleeplessness and cough. Sudden induction to such high altitude has profound effect on the body. It can lead to hypertension, blood coagulation disorders (intravascular blood coagulation, thromboembolism) and pulmonary hypertension. On the other hand, Ladakh people have adapted to this harsh climate and tagged to all the possible preventive measures taking into considerations the light food intake.

Effects of Climate Change on Distribution of Plants and Animal Particularly Yak at High Altitude

Global warming may cause a variety of risks to mountain habitats by affecting the distribution of plant and animal (Beckage et al. 2008). Parmesan and Yohe (2003) reported that a significant range shifts off many organisms towards the poles or towards higher altitudes as a consequence of increased global temperature. The climate change has complicated impacts on animals affecting distribution, growth and incidence of diseases, availability of fodder, productivity and even extinction of species in extreme cases due to habitat loss (Nardone et al. 2010). Yak is considered the lifeline of highland pastoral nomads who raise them on high altitude ranges under transhumance. Yak production at high-altitude alpine ranges may be affected due to the gradual increase of environmental temperature as a result of impending climate change. The transhumance pastoralism is the most common and popular adaptive method at the high altitudes to utilize the seasonal pastures. Traditionally, yak farmers used to migrate to higher altitudes during summer and return to lower altitudes called winter pastures at around 3000 m above msl during winter (Maiti et al. 2015). This transhumance pastoralism provides almost same ambient temperature year-round which is also one of the important practices to minimise the heat stress in yaks (Krishnan et al. 2016).

Impacts of Climate Change on Natural Resources

Farming communities of this cold desert hardly have access to a wide range of natural resource base as compared to plains do. Subsistent farming communities matter every inch of the valuable cultivated lands and water from snowmelt water to grow enough food only during one cropping season to last for the whole year. Farming was almost a communal practice with neighbours and relatives helping each other through the sowing and harvesting. Nomad communities follow migration plans and routes discovered every year for their livestock depending on the availability of pastures, climbing difficult and icy heights with their herd and making sure pretty much every blade of grass available was eaten. Postharvest produces preserved for harsh winter months.

Socio-economic Vulnerability

With the estimation of six factors, i.e. number of household, occupation, literacy status, assets, food sufficiency and public awareness to natural disaster, the socio-economic vulnerability was assessed which identified Debring, Tangtse and Nang villages as the most vulnerable amongsta six varied settlements, because of its weak adaptive capacity and almost all the village farmers/nomads had agricultural land ownership, indicating high dependency on agriculture and livestock to sustain their livelihood (Table 16.4) indicated the Vulnerability Indices (VI) which were then classified into three categories using "Three Categorized Ranking Method" (TCR) assigning scores of 1 to 3, 1 being the least vulnerable (Shrestha et al. 2003 in Shrestha 2005). Socio-economic vulnerability of a settlement was calculated by combining these six VI and Ranking of each VI are as also interpreted by Lama and Devkota (2009), given below:

- Higher household number in a settlement is associated with higher vulnerability.
- People with diversified occupation are considered less vulnerable and people involved only in agriculture are considered highly vulnerable.
- Lower level of literacy is associated with higher vulnerability.
- People having higher property investment are considered more vulnerable.
- Higher food deficiency is associated with higher vulnerability.
- Lower level of awareness to natural disaster and climate change and its adaptation and mitigation options are associated with higher vulnerability (Source: WWF Nepal 2008).

All the above villages were seriously affected by flash floods, and their agricultural cultivable lands were eroded replacing by boulders, frost heaves of pastures affected salts and desiccation with no soil (Fig. 16.6.).

Table 16.4 Socio-economic vulnerability assessment of the five settlements

Villages altitude	Situation	VI1	VI2	VI3	VI4	VI5	VI6	VI Combined	Vulnerability
Saboo 11,627 ft	Irrigated glacier-fed	2	2	1	2	1	1	1.50	L
Stakmo 12,675 ft	Semi-irrigated glacier-fed	2	2	2	2	2	2	2.00	M
Nang 11,755 ft	Dry and Rainfed glacier-fed	3	3	2	2	3	3	2.67	H
Chushot 11,755 ft	River bank salt-affected	2	1	1	2	1	1	1.33	L
Debring 16,100 ft	Changthang glacier-fed	3	3	3	2	3	3	2.83	H
Tangtse 13,501 ft	Changthang East glacier-fed	2	3	3	2	2	3	2.50	H

VI1 – No. of HHs, VI2- occupation, VI3- education, VI4- property value, VI5- food sufficiency, VI6- awareness; vulnerability: L = low, M = medium, H = high

Cultivable land eroded in Saboo | Frost heaves desiccated with no soil inside at Stakmo | Salt-affected frost heave and degraded pasture in Tangtse, Changthang

Fig. 16.6 Vulnerable villages – Saboo, Stakmo and Tangtse

Adaptation Measures

Only a few research projects have been carried out, and there is an urgent need to carry out detailed studies into better understanding the impacts of climate change on various aspects of human life and on potential short-term risks including landslides, avalanches, earthquakes, drought and locusts/disease hazards. Employment opportunities have greater impact on the communities. There is a need to develop appropriate employment opportunity as per the local tradition of the community. Religion provides key community support. Long-term financial risk adaptation also occurs at a small scale. Informal insurance schemes can be popular, and the binding of the agricultural economy with social structure means protection from loss is usually available (Chaudhuri 2000). Institutional planning for disaster response is formulated at national, state and district scales. The recent Indian Disaster Risk Management Programme has encouraged preparation and planning rather than emphasising relief. Jammu and Kashmir has a reasonably well-detailed disaster management plan that deals broadly with the variety of earthquakes, droughts and fires in the state (DRRR 2011). The research findings could also be used to inform the policy makers to design the climate resilient agricultural action plans.

Conclusion

Looking back from the current times of climate change vulnerabilities, the process of social, political and economic 'de-marginalisation' of the region that began in the 1960s, when the government, realising the strategic importance of the region, modernised the facilities to connect the region to rest of the country, has helped a large section of the subsistent farming communities living on the margins of development to seize new opportunities and be better prepared by the time climate change impacts became apparent and started hurting. Resilience-building adaptation strategies are vital to reduce the vulnerability of smallholder farmers mixed crop-livestock agriculture system applicable to Ladakh condition. Ladakhi communities need governmental attention and its policies as well as society support in coming to terms with these changes and adapting their lives and livelihoods around them.

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Chapter 17
Food Security and Land Use Change Under Conditions of Climate Variability: Synthesis and Uniting Perspectives

Victor R. Squires and Mahesh K. Gaur

Introduction

Food security is a multifaceted and multidimensional matter (Squires et al. 2015). According to Robinson and Carson (2015) in the past few decades, there has been radical restructuring of the scope and character of the production and distribution of many goods, including food. This process has been called "globalization," shaping peoples' lives in profound cultural, ideological, and economic ways. The development of globalization is qualitatively different from the internationalization of world trade that developed in the nineteenth century. Globalization impinges on food security in many different ways.

The topic of food security covers aspects at all spatial levels from local to global, and from an interdisciplinary and systemic food systems perspective. We sought to take a synthetic view of the sociology, science, and economics of food production. This necessitates consideration of agricultural development, access to food, and nutritional adequacy (Fig. 17.1).

This book aims to better understand environmental, nutritional, agricultural, demographic, socioeconomic, political, technological, and institutional drivers, costs, and outcomes of current and future food security. Interactions with contextual factors include climate change, urbanization, greening the economy, and data-driven technologies. Some contributions are on cross-cutting topics, addressing availability, access, and utilization in an integrated way.

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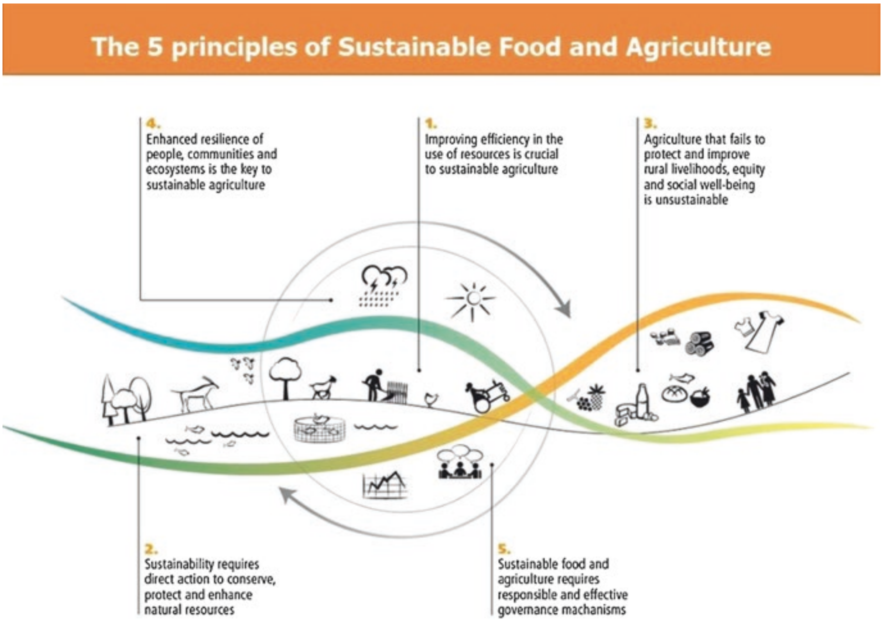

Fig. 17.1 Five principles of sustainable food and agriculture that are a foundation for food security. (Source: FAO 2013)

We sought to address these topics, either in specific chapters or across the spectrum of the whole book all set against the impact of climate variability. Human-environmental interactions are extremely complex and can be obscured not only by the dynamic complexity of societal response (Gaur and Squires 2019) and human adaptation (Feng and Squires 2018) to the changing landscape (Adger et al. 2003). Societal response to climate variability greatly varies and relies in part on a particular level of cultural sophistication and stage of economic development that can seldom be measured.

Key elements canvassed in this book are as follows, but not all aspects are treated in the same depth. Some contributions are on cross-cutting topics, addressing availability, access, and utilization in an integrated way.

1. Food security and the Sustainable Development Goals: synergies, tensions, and trade-offs
2. Circularity of food systems at local, regional, or global levels
3. Food security and policy, governance, institutions, and trade
4. Transitions to post-carbon food systems in a post-carbon economy
5. How to assess future food security: on foresight, forecasting, projecting, predicting, and exploring the future
6. Influencing and moderating food consumption and demand (considering the food environment)
7. Availability: production, distribution, and exchange of food
8. Access: affordability, allocation, and preference of food

9. Utilization: nutritional value, social value, and safety of food
10. Stability and dynamics of food security aspects

Not everyone in the world enjoys secure access to food. The factors that can cause food insecurity are often multiple and interrelated, including:

- Access to farming land
- Land “grabbing”
- Biofuels
- Natural disasters and climate change
- Conflict
- Food wastage
- The “financialization” of food
- Market dominance of multinational agribusinesses and exporters
- Unfair trade rules

As the list of issues above shows, the term “food insecurity” does not always capture the complex factors that hinder people’s access to nutrition. Proper nutrition is not always simply about access to food. It is also about economic, social, and political participation. It is about systems of food production and distribution as much as farming techniques. It is about actions taken in the developed world as much as about issues experienced in the developing world. “Food sovereignty” is a concept used to ensure that these wider issues that impact on people’s food security are not ignored (Altieri et al. 2012). Food sovereignty covers both the right to food and the right of people and communities to have a say in the sources of their food. It’s not just about having enough food, it’s also about access to resources such as land, water, seeds, and biodiversity.

The topic of food security covers aspects at all spatial levels from local to global, and from an interdisciplinary and systemic food systems perspective. The book aims to better understand environmental, nutritional, agricultural, demographic, socioeconomic, political, technological, and institutional drivers, costs, and outcomes of current and future food security. Interactions with contextual factors include climate change, urbanization, sustainability issues, and greening the economy.

Food Security in an Insecure Future

Food security is taken for granted in the industrialized world, where stable political and social structures ensure that everyone has access to safe and nutritious food sufficient to maintain a healthy and active lifestyle. The picture in the developing world is very different. One of the persistent myths concerning food insecurity is that it is caused by a shortfall in food production. Quite to the contrary, there is plenty of food to go around. The reasons for food insecurity are complex, but one of the main factors is poverty. Despite the wealth present in Western society (Europe, North

America, etc.), high rates of food insecurity, food insufficiency, and hunger are a significant problem in places. Some adults have obsessive concerns about their food supply – this may, in part, be a symptom of materialistic tendencies developed in childhood in response to an insufficient food supply. Concerns regarding the security of the national food supply are certainly not limited to one country. However, in Asia and parts of Africa, this preoccupation stretches back millennia, in part due to the limited areas of arable land that has had to feed a large population and in part due to the sad history of natural disasters to which much of these regions are prone.

We will first explore the concept of food self-sufficiency and its implications for current food security policies. For some countries, e.g., China and Ethiopia, food security has acquired a very specific meaning that emphasizes maintaining basic food availability, rather than variety or quality of food. Food safety is an integral part of food security; yet, because of the long-standing focus on maintaining basic food availability, until very recently food safety was not high on the list of priorities.

As global food security deepens owing to declining agricultural productivity as a result of climate change, shortages of fertile land and water to expand production, and high population growth in the developing world, agricultural development and food security are at top of the development agenda (Burlingame and Dernini 2012).

Arable land area per capita is declining on a global scale because of population growth, conversion of agricultural land to other uses (e.g., urban expansion, infrastructure), and soil degradation (Squires et al. this volume, present data from selected countries in Africa and Asia to show the shrinking land base for food production). Gaur and Squires (2019) in their book *Climate variability impacts on land use and livelihoods in Drylands* explore the issue of climate change and its incremental impact that adds to the problem of producing more food from a rapidly shrinking land base.

The world's population grew from about 0.6 billion people in 1770 to 6 billion in 2000. Over the same period, the world's arable land grew only half as fast, from 0.3 billion hectares to 1.5 billion hectares. Many countries face now or are likely to encounter serious challenges of land scarcity that affect about 2 billion people in 2020 (Table 17.1).

Food security is directly affected by a challenging combination of ongoing destructive conflicts, a global economic downturn, widespread poverty, high population growth, corruption, intolerance, and the potentially damaging consequences

Table 17.1 Global estimates of land-scarce populations (billions of people)

Year	Low projection	Medium projection	High projection
1990	0.3	0.3	0.3
2000	0.3	0.3	0.4
2010	0.5	2.0	2.1
2020	0.8	2.3	2.4
2030	1.0	2.8	3.5
2040	1.4	3.5	4.2
2050	1.4	3.8	4.7

of climate change. Many countries demonstrate nearly all the features of those countries classified as poor, less developed, or failing to achieve the eight Millennium Development Goals. Even the economies of the richer oil-exporting countries have been seriously damaged by the downturn in oil and gas prices as new sources come on stream elsewhere and demand falls as a result of renewable sources of energy becoming available.

The disruptions from food insecurity, natural disasters, and forced displacement are compounded by state fragility and weak institutions, yielding complex and persistent humanitarian emergencies (IFPRI 2017). Malnutrition is nothing new for many Indians and Africans, in particular. According to the International Food Policy Research Institute's GHI, the upshot of this perennial problem is that about 60 million children in India are underweight and malnourished, while 21% of the population as a whole generally is malnourished. The developmental repercussions of this situation are dramatic, not only for individuals who suffer numerous health issues resulting from malnutrition but also for the economy at large. Malnutrition results in a loss of productivity, indirect losses from impaired cognitive development, and losses from increased long-term healthcare costs (Alderman et al. 2006).

Hunger, Famine, and Malnutrition

Malnutrition in all its forms – undernutrition, micronutrient deficiencies, and overweight and obesity – imposes unacceptably high economic and social costs on countries at all income levels. Improving nutrition and reducing these costs requires a multisectoral approach that begins with food and agriculture and includes complementary interventions in public health and education. The traditional role of agriculture in producing food and generating income is fundamental, but the entire food system – from inputs and production, through processing, storage, transport, and retailing, to consumption – can contribute much more to the eradication of malnutrition (FAO 2013).

According to IFPRI (2011), 26 countries still have levels of hunger that are "extremely alarming" or "alarming." The countries with extremely alarming 2011 GHI[1] scores – Burundi, Chad, the Democratic Republic of the Congo, and Eritrea – are in Sub-saharan Africa. Most of the countries with alarming GHI scores are in Sub-saharan Africa and South Asia. Among the six countries in which the hunger situation worsened, the Democratic Republic of the Congo stands out. Its GHI score rose by about 63% owing to conflict and political instability.

Seen in a historical perspective, food insecurity has fallen dramatically worldwide. In 1991–1992, 1.2 billion people were undernourished globally, with that number declining to 991 million in the 2000s and 821 million in 2017 (FAO et al.

[1] The Global Hunger Index (**GHI**) is a tool designed to comprehensively measure and track hunger at the global, regional, and country levels. The **GHI** is designed to raise awareness and understanding of the struggle against hunger.

2018). However, the number of undernourished people (i.e., those facing chronic food deprivation) has increased over the last 3 years. Furthermore, over 124 million people were reported to face crisis levels of food insecurity in 2017, up from 100 million in the preceding year (FSIN 2018[2]). In early 2017, a famine was declared in South Sudan[1], and alerts went out to signal high risk of famine-like conditions in northeast Nigeria, Somalia, and Yemen. Similarly, the frequency of conflicts had decreased in recent decades but increased recently. The number of violent conflicts and the number of conflict-related deaths have increased (UCDP 2018; Allansson et al. 2017).

For example, according to a report by the World Bank, productivity losses in India due to stunted growth, iodine deficiencies, and iron deficiencies are equivalent to almost 3% of GDP. While during the colonial era, famine was the primary result of "food insecurity," malnutrition has replaced it as the chief concern of legislators and economists. The current situation in India is not so much a lack of nutrient-rich food, but rather a weakness in the food supply chain. Inefficiencies in the downstream segments of the food supply chain are still rampant and threaten to undermine self-sufficiency and perpetuate malnutrition while the price for consumers is marked up by as much as 60%. High prices for the consumer, as well as limited quantity and quality, all resulting from supply chain inefficiency, are sustaining increased malnutrition among the poor population. Market distortions, along with vested interests by middlemen in perpetuating the existing lengthy supply chains, will continue to plague the population of India for some time. The result of this sad situation will surely be a continuation of the ongoing malnutrition epidemic, which will continue to handicap an already slowing economy.

Sustainable Food Systems

According to FAO (2013), food systems encompass all the people, institutions, and processes by which agricultural products are produced, processed, and brought to consumers. They also include the public officials, civil society organizations, researchers, and development practitioners who design the policies, regulations, programs, and projects that shape food and agriculture. Food systems rely on a natural resource base that is becoming increasingly more fragile and scarce and that is extremely vulnerable to climate change as well as biodiversity loss – both of which are undermining food security and nutrition (IPCC, Climate Change; 2014). Traditional and modern food systems coexist and evolve as economies grow and urbanization increases (see below). The most dramatic ecological effect of agricultural expansion on biodiversity has been habitat destruction, which, along with soil erosion and the intensive use of agrichemicals (e.g., pesticides and fertilizers), has combined to threaten biodiversity at a global scale (Gomiero 2015).

[2]The **Food Security Information Network** (FSIN) is a global initiative cosponsored by FAO, WFP, and IFPRI to strengthen food and nutrition security information systems for producing reliable and accurate data to guide analysis and decision-making.

The generation of farmers now on the land is the first to face man-made climate change. Agriculture as it exists today developed over 11,000 years of rather remarkable climate stability. It has evolved to maximize production within that climate system. Now, suddenly, the climate is changing. With each passing year, the agricultural system is more and more out of sync with the climate system. At no time since agriculture began has the world faced such a predictably massive threat to food production as that posed by the melting mountain glaciers. Much of Greater Central Asia, including the Qinghai-Tibet Plateau, depends on irrigation on glaciers that are now melting. Mountain glaciers are melting in the Andes, the Rocky Mountains, the Alps, and elsewhere. But nowhere does melting threaten world food security more than in Asia where the glaciers of the Himalayas and on the Tibetan Plateau that feed the major rivers of India and China are retreating (Hagg 2018; Shang et al. 2019). Ice melt helps sustain these rivers during the dry season (Raghuvanshi et al. 2019). In the Indus, Ganges, Yellow, and Yangtze River basins, where irrigated agriculture depends heavily on rivers, the loss of glacial-fed, dry-season flow will shrink harvests and could create potentially unmanageable food shortages.

Farmers worldwide are expected to grow more food with limited resources without causing depletion of limited resources. At the same time, policy aimed at enhancing agricultural production, subsidizing agricultural farms, and reducing the environmental impact of farming is essential for future global food security. Sustainable forms of agriculture have emerged in response to the challenge of balancing optimum resource management with maximum production and can lead to both economic and environmental benefits to farmers, communities, and nations in the long term.

Sustainable food systems play an important role in increasing resource efficiency, more sustainable use of resources, and building resilience in communities responding to a rapidly changing global environment. There are two main elements – sustainability of the production base and sustainable diets that provide sustenance and ward off symptoms of malnutrition. The objective is to achieve a sustainable dietary pattern, in which nutrition, food, cultures, people, environment, and sustainability all interact into a new model of a sustainable diet.

Sustainable diets are defined as follows: "*Sustainable Diets are those diets with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy; while optimizing natural and human resources*" (Burlingame et al. 2012). The notion of sustainable diets acknowledges the interdependencies of food production and consumption with food requirements and nutrient recommendations and, at the same time, reaffirms the notion that the health of humans cannot be isolated from that of ecosystems (Burlingame et al. 2011). The concept of sustainable diets involves economic, environment, and sociocultural issues which influence nutrition and health outcomes. Integrating the notion of sustainable diets with the food chain approach, i.e., "getting biodiversity from the farm to the plate," provides an innovative inter-sectoral effort to counteract the simplification of diets, loss of biodiversity, and the degradation of ecosystems and to prevent further erosion of food cultures.

Smallholders

One of the agricultural pathways toward sustainable food and nutrition security is through local production of nutritious food, activity in which smallholder farmers play a crucial role. Smallholder farms in developing countries are key to global food security and sustainability of agricultural systems (Goswami and Dasgupta 2017). As food consumers, all rural and urban people in developing countries count heavily on the efficiency of their local smallholder farmers to satisfy their food needs. It is a proven fact that deep and rapid changes are taking place in the food systems from production to consumption, with strong implications for rural-urban linkages and smallholder livelihoods (Squires and Gaur this volume; Donkor et al. 2019). The effects of change include the exclusion of large numbers of smallholders from the more dynamic markets; the concentration of a greater share of value added in the downstream segments of the food system; the weakening of traditional wholesale and retail; a strengthening of the relative weight of non-primary activities in the rural-urban economy creating new employment; and the increased presence of highly processed food, including in the diet of the urban and the rural poor. Actions at the rural-urban interface can help improve the conditions and outcomes of the participation of smallholder farmers and of household and small and medium entrepreneurs. For the vast majority of the 500 million smallholders in the world, because the proportion of smallholders that gain entry to the more dynamic segments of the food markets, through direct transactions from the farm to the processor, modern specialized wholesaler, modern retailer, or consumer, is tiny, there will continue to be heavy reliance on self-consumption and sale of surplus produce in local markets.

Food: Paradigms, Perceptions, and Policy

According to Vermeulen et al. (2012), food systems contribute 19–29% of global anthropogenic greenhouse gas (GHG) emissions, releasing 9800–16,900 megatons of carbon dioxide equivalent ($MtCO_2e$) in 2008. Agricultural production, including indirect emissions associated with land-cover change, contributes 80–86% of total food system emissions, with significant regional variation. The impacts of global climate change on food systems are expected to be widespread, complex, geographically and temporally variable, and profoundly influenced by socioeconomic conditions. Historical statistical studies and integrated assessment models provide evidence that climate change will affect agricultural yields and earnings, food prices, reliability of delivery, food quality, and, notably, food safety. Low-income producers and consumers of food will be more vulnerable to climate change owing to their comparatively limited ability to invest in adaptive institutions and technologies under increasing climatic risks. Some synergies among food security, adaptation, and mitigation are feasible. But promising interventions, such as agricultural intensification or reductions in waste, will require careful management to distribute costs and benefits effectively. Food systems overlap with agricultural systems in the area of food production but also comprise the diverse set of institutions, technologies, and practices that govern the way food is marketed, processed, transported, accessed, and consumed. A sustainable food system supports food security; makes optimal use of natural and human resources; is culturally acceptable and accessible, environmentally sound, and economically fair and viable; and provides the consumer with nutritionally adequate, safe, healthy, and affordable food for present and future generations (Capone et al. 2014; Emadi and Rahmanian this volume).

Industrial agriculture refers to a process of mechanizing the growing, harvesting, and processing of food. Rather than having a multitude of small family farms producing a variety of healthful, wholesome foods, we have huge, multinational, multibillion-dollar corporations that have maximized their ability to provide food by making every natural step in the life cycle of a crop or animal more "efficient" through the application of science and engineering. While it has led to greater (and cheaper) products like milk, eggs, and meats, there has been concern expressed about the environmental impact, the conditions under which animals are housed and fed, the work environment for employees, and animal welfare considerations.

Farming systems fall along gradients between three philosophical poles – industrial, agrarian, and ecological. Different systems will be appropriate in different contexts. Intensification of agriculture has produced such efficiencies as the commonly claimed success of feeding a nation from the work of only 4% of the population. But that 4% is only a fraction of the food supply network. Others include buyers at various levels, retail outlets, processing facilities, packaging, transporters, and infrastructure supporting all these and other fields from the physical structures through to banking and input supplies including chemicals, feeds, and pharmaceuticals. Within this paradigm, stewardship and integrity with nature cannot be credible concepts unless they include all involved in the food industries, including consumers. Regrettably, we are far from this level of holism in modern agriculture.

Despite evidence for lower yields in organic crop systems, Shennan et al. (2019) found considerable evidence for environmental and social benefits from adopting what Rausser et al. (2019) call the *Naturalist Food Paradigm*. Tradeoffs imposed by such practices suggest that their contributions to obesity reduction in the developed world, alleviation of hunger and malnutrition among poor populations, and avoidance of environmental pollution and biodiversity loss are highly uncertain.

Some have been calling for economic and policy overhauls of the food system – touching upon human health, labor rights, the environment, climate change, and animal welfare. Current findings (Rausser et al. 2015) demonstrate that restrictions on industrial practices imposed by policy or consumer preferences sacrifice productivity, thereby imposing environmental costs and raising food prices. Such restrictions may also reduce choice sets of consumers, impeding consumer and producer welfare gains. The intended benefits of such practices for human, animal, or environmental well-being must be weighed against the costs they impose.

Food production (namely, grain), inputs (fertilizer, water), and outputs (state of environment) are vital elements to a sustainable food system that must be considered along with consumers (people, animals) and where consumers are located (urban, rural). The world has urbanized, but it has not done so exclusively or even mainly in large cities. Almost 2 billion people, or half of the world's urban population, reside in towns and small and medium cities of up to half a million inhabitants; this is about 27% of the world's total population[1] (Fig. 17.2). An additional 3.4 billion people are classified as living in rural areas, or 46% of our planet's inhabitants. The urban population of the world has grown rapidly from 746 million in 1950 to 7.6 billion in May 2018. Asia, despite its lower level of urbanization, is home to 53% of the world's urban population, followed by Europe with 14% and Latin America and the Caribbean with 13%.

In addition, the majority of the world's poor, perhaps as many as 70%, live in these towns and small and medium cities and the rural areas more proximate to them. About 5.5 billion persons, three quarters of all of us on Earth, live in the increasingly diffuse and porous interface of rural and urban societies. Moreover, poverty rates are also higher in small and medium cities than in large urban agglomerations (Ferré et al. 2012), even in a country with huge numbers of people living in the slums of large cities, like in India.

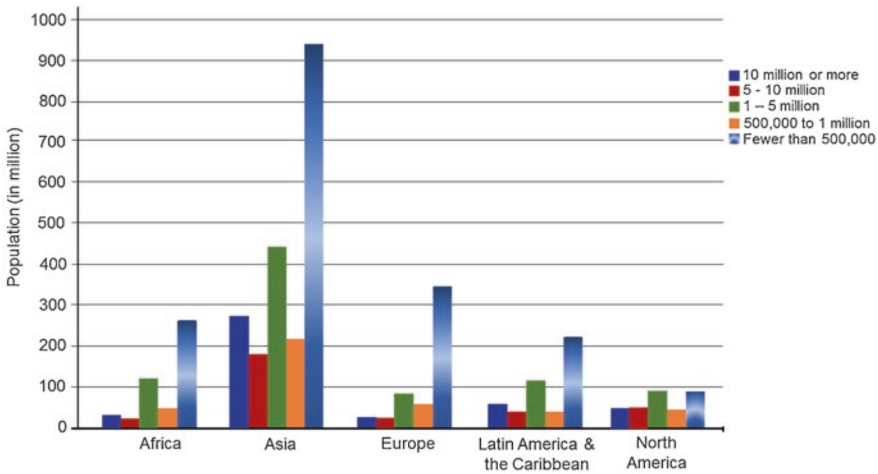

Fig. 17.2 Small- and medium-size cities housed a majority of the urban people in the world by 2015, but the proportion of urban dwellers on a global basis is projected to be over 63% by 2050. (Source: Updated by the authors with data from the World Urbanization Prospects (UNDESA 2014), following Roberts and Hohmann 2014)

Agricultural Productivity and Food Security

Links between land quality[3] agricultural productivity and food security are intuitively reasonable but complex (Squires and Gaur this volume). Empirical analysis of these links has historically been limited by data constraints and disciplinary boundaries (Weibe 2003). Agricultural productivity affects food security through its impacts on both food supplies and farmers' incomes. Food security in turn influences farmers' practices that affect land quality over the longer term. Food security per se also influences farmers' practices that affect land quality over the long term.[4]

Despite the challenges we must gain a better understanding of the projected changes in land quality, land degradation, agricultural productivity, and food security at the policy-relevant scale. We need to consider the role of the farmers' decisions, not just in terms of maximizing income in the short term but also in terms of sustaining income over the longer term by investing in the maintenance or improvement of land quality. This applies whether we are dealing with small-scale subsistence farmers or farmers driven by commodity prices in the commercial farming world. The result is not a simple linear relationship that begins with exogenous land quality and traces causality through to agricultural productivity and food security in a single period, but rather a dynamic process in which each element influences the others over time (Squires and Gaur this volume).

Just as land quality includes climate and hydrologic characteristics that affect land's ability to provide goods and services, land degradation includes changes in those characteristics – including water resources – that reduce land's ability to produce goods and services. Depletion of water resources poses at least as important challenge for agricultural productivity and food security as do the more commonly considered aspects of land degradation and soil loss (see chapter by Nagabhatla et al. this volume; Bekchanov et al. 2018). It has been concluded by Weibe (2003) that land degradation appears to generate productivity losses that are relatively small on a global scale but that both productivity losses and their food security consequences are likely to be significantly greater in area where fragile resources are found in conjunction with poverty and poorly functioning markets and institutions.

[3] Land quality refers to the ability of land to produce goods and services that are valued by humans. This ability derives from inherent/natural attributes of soils (e.g., depth and fertility), water, climate, topography, vegetation, and hydrology as well as "produced" attributes such as infrastructure (e.g., irrigation, transportation routes) and proximity to population centers.

[4] Agricultural productivity is critical to food security because it affects both the incomes of those whose livelihoods depend on agriculture (including animal husbandry) as well as the supply of food (and these food prices) for all consumers.

Land Degradation and Changes in Land Use and Agricultural Productivity Over Time

Agricultural productivity at various spatial scales changes over time as a result of changes in land quality. Planning horizons are intimately related to farmers' property rights/use rights in land. Poverty also plays an important role in the management of marginal and often fragile lands (both cropland and grazing land). Most studies on the effects of land degradation focus on selected measures of productivity, but land degradation may affect food security as well, through its impact on food production as well as on incomes and food prices. Biotechnology provides a range of tools that can be used to improve agriculture in the developing world. Some technologies rely on molecular biology to improve yields and improve resistance to pests and diseases or to cope better with soil and water salinity relates. Others relate to farm mechanization, to improved irrigation. The adoption of climate-smart agriculture (Attia-Ismail 2019) is on the rise. The nexus between water, food, and energy is a juncture where advances can be made.

Falling water tables, eroding soils, and rising temperatures make it difficult to feed growing populations (Gaur and Squires, this volume). As a result, control of arable land and water resources is moving to center stage in the global struggle for food security (Nagabhatla et al. this volume). Nearly a third of the world's cropland is losing topsoil faster than for new soil to form. This reduces the land's inherent fertility. Future food production is also threatened by soil erosion – a serious global phenomenon (Gaur and Squires this volume). The thin layer of topsoil that covers the Earth's land surface was formed over long stretches of geological time as new soil formation exceeded the natural rate of erosion. Sometime within the last century, the situation was reversed as soil erosion began to exceed new soil formation. Now, nearly a third of the world's cropland is losing topsoil faster than for new soil to form. Soil that was formed on a geological time scale is being lost on a human time scale. "Peak soil" is now history as the rate of loss exceeds soil formation.

To meet the global food human needs by 2050, the world's agricultural system must simultaneously produce far more food for a growing population, provide economic opportunities for the rural poor who depend on agriculture for their livelihoods, and reduce environmental impacts. Figuring out how to feed 9.6 billion people (Godfray et al. 2010) while also advancing rural development, reducing greenhouse gas emissions, and protecting valuable ecosystems is one of the greatest challenges of our era. The challenge of feeding the growing world population, which is expected to reach 9 billion people in 2050, requires new strategies and new multicultural and multi-sectorial rethinking capable of generating new forms of dialogue, at different specialist levels, toward a more sustainable use of the available natural and human resources, to ensure food and nutrition security. Food consumption and production trends and patterns are among the most important drivers of environmental pressures. Eating patterns, which are important drivers for agricultural and food systems, are often neglected in the research and policy areas. Food consumption is variably affected by a whole range of factors including food availability, food accessibility, and food choice, which in turn may be influenced by geography, demography, disposable income, socioeconomic status, urbanization, globalization, religion, culture, marketing, and consumer attitude.

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