Edited by Clayton Campanhola
and Shivaji Pandey

Sustainable Food and Agriculture

An Integrated Approach

Food and Agriculture Organization of the United Nations

SUSTAINABLE FOOD AND AGRICULTURE

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An Integrated Approach

Edited by

CLAYTON CAMPANHOLA

The Food and Agriculture Organization of the United Nations (FAO), Rome, Italy

SHIVAJI PANDEY

Special Advisor to the Food and Agriculture Organization of the United Nations (FAO), Rome, Italy

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Contents

List of Contributors

José Aguilar-Manjarrez Food and Agriculture Organization of the United Nations (FAO), Rome, Italy
Arwen Bailey Bioversity International, Maccarese, Italy
Jennie Barron Swedish University of Agricultural Sciences, Uppsala, Sweden; CGIAR Research Program on Water, Land and Ecosystems, Colombo, Sri Lanka
Caterina Batello Food and Agriculture Organization of the United Nations (FAO), Rome, Italy
Lorenzo Giovanni Bellù Food and Agriculture Organization of the United Nations (FAO), Rome, Italy
Zareen Pervez Bharucha Anglia Ruskin University, Cambridge, United Kingdom
Kartika Bhatia Middle East and North Africa Office, World Bank, Washington, DC, United States
Regina Birner Institute of Agricultural Sciences in the Tropics (Hans-Ruthenberg-Institute), University of Hohenheim, Stuttgart, Germany
Sally Bunning Food and Agriculture Organization of the United Nations (FAO), Santiago, Chile
Clayton Campanhola Strategic Program Leader (Sustainable Agriculture), Assistant Director-General (Economic and Social Development Department), and Special Advisor (Sustainable Agriculture), respectively, of the Food and Agriculture Organization of the United Nations (FAO), Rome, Italy
Andrea Cattaneo Food and Agriculture Organization of the United Nations (FAO), Rome, Italy
Molly Conlin CGIAR Independent Science and Partnership Council, c/o Food and Agriculture Organization of the United Nations (FAO), Rome, Italy
Valerio Crespi Food and Agriculture Organization of the United Nations (FAO), Rome, Italy
Ben Davis Food and Agriculture Organization of the United Nations (FAO), Rome, Italy
Jeroen Dijkman CGIAR Independent Science and Partnership Council, c/o Food and Agriculture Organization of the United Nations (FAO), Rome, Italy
Kumuda Dorai LINK limited, Canberra, ACT, Australia
Paul Dorosh International Food Policy Research Institute (IFPRI), Washington, DC, United States
Ehsan Dulloo Bioversity International, Maccarese, Italy
Shenggen Fan International Food Policy Research Institute (IFPRI), Washington, DC, United States
Jean-Marc Faurès Food and Agriculture Organization of the United Nations (FAO), Rome, Italy

Edith Fernández-Baca United Nations Development Program (UNDP), Lima, Peru
Cornelia Butler Flora Kansas State University, Manhattan, KS, United States
Louise O. Fresco Wageningen University and Research, Wageningen, Netherlands
Lucy Garret Food and Agriculture Organization of the United Nations (FAO), Rome, Italy
Hafez Ghanem Middle East and North Africa Office, World Bank, Washington, DC, United States
Marius Gilbert Spatial Epidemiology Lab (SpELL), Free University of Brussels, National Fund for Scientific Research, Brussels, Belgium
Meredith Giordano International Water Management Institute (IWMI), Colombo, Sri Lanka
Andrew Hall Agriculture and Food, Commonwealth Scientific and Industrial Research Organisation (CSIRO), Black Mountain, Canberra, ACT, Australia
Matthias Halwart Food and Agriculture Organization of the United Nations (FAO), Rome, Italy
Sue Hartley University of York, York, United Kingdom
Patrick P. Kalas Food and Agriculture Organization of the United Nations (FAO), Rome, Italy
Gina Kennedy Bioversity International, Maccarese, Italy
Zeyaur Khan International Centre of Insect Physiology and Ecology (ICIPE), Nairobi, Kenya
Misael Kokwe Food and Agriculture Organization of the United Nations (FAO), Lusaka, Zambia
Rattan Lal Ohio State University, Columbus, OH, United States
Wilfrid Legg Consultant and formerly OECD
Preet Lidder CGIAR Independent Science and Partnership Council, c/o Food and Agriculture Organization of the United Nations (FAO), Rome, Italy
Leslie Lipper CGIAR Independent Science and Partnership Council, c/o Food and Agriculture Organization of the United Nations (FAO), Rome, Italy
Juliana C. Lopes Food and Agriculture Organization of the United Nations (FAO), Rome, Italy
Yuelai Lu University of East Anglia, Norwich, United Kingdom
Eduardo Mansur Food and Agriculture Organization of the United Nations (FAO), Rome, Italy
Alexandre Meybeck Bioversity International (CIFOR), Maccarese, Italy
Weimin Miao Food and Agriculture Organization of the United Nations (FAO), Bangkok, Thailand
Charles Midega International Centre of Insect Physiology and Ecology (ICIPE), Nairobi, Kenya
Jamie Morrison Food and Agriculture Organization of the United Nations (FAO), Rome, Italy
William Murray Food and Agriculture Organization of the United Nations (FAO), Rome, Italy

David Neven Food and Agriculture Organization of the United Nations (FAO), Rome, Italy

Hanh Nguyen Food and Agriculture Organization of the United Nations (FAO), Rome, Italy

Ephraim Nkonya International Food Policy Research Institute (IFPRI), Washington, DC, United States

Carolyn Opio Food and Agriculture Organization of the United Nations (FAO), Rome, Italy

Shivaji Pandey Strategic Program Leader (Sustainable Agriculture), Assistant Director-General (Economic and Social Development Department), and Special Advisor (Sustainable Agriculture), respectively, of the Food and Agriculture Organization of the United Nations (FAO), Rome, Italy

Monica Petri Food and Agriculture Organization of the United Nations (FAO), Vientiane, Laos

Ugo Pica-Ciamarra Food and Agriculture Organization of the United Nations (FAO), Rome, Italy

John Pickett Rothamsted International, United Kingdom

Prabhu Pingali Tata-Cornell Institute for Agriculture and Nutrition, Cornell University, Ithaca, NY, United States

Jimmy Pittchar International Centre of Insect Physiology and Ecology (ICIPE), Nairobi, Kenya

Jules Pretty University of Essex, Colchester, United Kingdom

Ewald Rametsteiner Food and Agriculture Organization of the United Nations (FAO), Rome, Italy

Sherman Robinson International Food Policy Research Institute (IFPRI), Washington, DC, United States

Timothy Paul Robinson Food and Agriculture Organization of the United Nations (FAO), Rome, Italy

Dominic Rowland Center for International Forestry Research (CIFOR), Bogor, Indonesia; SOAS, University of London, London, UK

Harpinder Sandhu Flinders University, Adelaide, SA, Australia

Fritz Schneider Bremgarten, Switzerland

Rachid Serraj CGIAR Independent Science and Partnership Council, c/o Food and Agriculture Organization of the United Nations (FAO), Rome, Italy

Andrea Sonnino Agenzia Nazionale per le Nuove Tecnologie, L'Energia e lo Sviluppo Economico Sostenible (ENEA), Biotechnologies and Agroindustry Division, Casaccia Research Centre, Rome, Italy

Kostas Stamoulis Strategic Program Leader (Sustainable Agriculture), Assistant Director-General (Economic and Social Development Department), and Special Advisor (Sustainable Agriculture), respectively, of the Food and Agriculture Organization of the United Nations (FAO), Rome, Italy

Austin Stankus Food and Agriculture Organization of the United Nations (FAO), Rome, Italy

Henning Steinfeld Food and Agriculture Organization of the United Nations (FAO), Rome, Italy

Rudresh Kumar Sugam Formerly Council on Energy, Environment and Water, New Delhi, Delhi, India

Terry C.H. Sunderland Center for International Forestry Research (CIFOR), Bogor, Indonesia; Faculty of Forestry, University of British Columbia, Vancouver, Canada

Berhe Tekola Food and Agriculture Organization of the United Nations (FAO), Rome, Italy

James Thurlow International Food Policy Research Institute (IFPRI), Washington, DC, United States

Olcay Ünver Food and Agriculture Organization of the United Nations (FAO), Rome, Italy

Cora van Oosten Centre for Development Innovation, Wageningen University, Wageningen, Netherlands

Rob Vos International Food Policy Research Institute (IFPRI), Washington, DC, United States

Ren Wang Beijing Genomics Institute, Shenzhen, P.R. China

Keith Wiebe International Food Policy Research Institute (IFPRI), Washington, DC, United States

Wei Zhang International Food Policy Research Institute (IFPRI), Washington, DC, United States

Foreword

Today, the world still produces food mainly based on the principles of the green revolution of the 1960s and 1970s. Most of this production is based on high-input and resource-intensive farming systems at a high cost for the environment. As a result, soil, forests, water, air quality, and biodiversity continue to degrade. And this focus on increasing production at any cost has not been sufficient to eradicate hunger, despite the fact that today we produce more than enough to feed everyone. In addition, we are seeing a global epidemic of obesity. This is situation is unsustainable, and we have reached an inflection point. We need to promote a transformative change in the way we produce and consume food. We need to put forward sustainable food systems that offer health and nutritious food to everyone, and also preserve the environment.

Achieving the 2030 Agenda for Sustainable Development requires us to make this transformative change with people at its center. This publication can serve as a reference in that process. It shows what viable options look like and how various efforts have succeeded or fallen short. The data and examples provide a compelling case for an integrated approach—in which social, economic, and environmental considerations are all considered. A roadmap is sketched to highlight the policy and technology options that can make agriculture more productive both across sectors and over the long term. This text offers detailed ideas on assuring inclusive and effective governance at different levels, including suggestions for balancing trade-offs, monitoring progress, and building partnerships.

Promoting sustainable agriculture and healthy diets means taking action at each and every link in the food chain. The judicious use of technologies and innovative practices, supported by appropriate policies, institutions, and incentives can help the world meet its present needs without jeopardizing the opportunities of future generations. That is what "sustainable production and consumption" is all about.

Whether countries and communities across the globe opt for climate-smart agriculture, sustainable intensification, agroecology, biotechnologies, or any of the other approaches laid out here to make agriculture more sustainable—and to eradicate hunger and poverty—the FAO stands ready to provide expertise and support throughout the value chain. Agricultural production should go beyond increasing yields, providing new job opportunities for women, men, and youth in crop, livestock, forestry, fisheries, and aquaculture production as well as in research and innovation and after-harvest activities such as storing, processing, transporting, and marketing.

Many interrelated challenges are converging, and the choices we make at this important crossroads will determine whether we achieve a world free of poverty, hunger, disease, and want. When resource use is efficient, the environment is protected, rural livelihoods,

equity, and social well-being are improved, resilience is enhanced, and responsible and effective governance mechanisms are in place in agriculture, we will have the change that is warranted, and people and the planet will benefit together.

José Graziano da Silva

Director-General

Food and Agriculture Organization of the United Nations

Preface

Currently, the world's agriculture and food systems face the future challenge of providing 50 percent more food than the total needed in 2013 to feed a population of 9.73 billion by 2050. More urbanized and affluent than ever before, that population will demand more livestock-based and processed foods and fruits and vegetables. However, even for current levels of population and consumption, our agriculture and food systems are proving inadequate. Despite systems producing enough food to meet the caloric requirements of the current population, 815 million people remain hungry, 2 billion suffer from micronutrient deficiencies, and 40% of the population above 18 years of age is overweight; the natural resources that underpin agriculture and food systems are under pressure (e.g., one-third of agricultural land is moderately to highly degraded, agriculture uses 70% of all water withdrawal and causes environmental pollution, and food production is responsible for 75% of the loss in agrobiodiversity); and the agricultural production systems, including deforestation, contribute to 29% of the global greenhouse gas emissions for climate change, which is already impacting the livelihoods of the most vulnerable, especially in rural areas.

So, how will global agriculture and food systems "meet the needs of the present without compromising the ability of future generations to meet their own needs" in 2050 and beyond? Over the years, some initiatives to enhance productivity and sustainability of different agricultural sectors have been launched (e.g., Save and Grow for the crop sector, Global Agenda for Sustainable Livestock, Sustainable Forest Management, the Code of Conduct for Responsible Fisheries, and Climate-Smart Agriculture, among others). The Food and Agriculture Organization of the United Nations recently launched a new vision for and approach to promoting sustainable food and agriculture that requires explicit consideration of cross-sectoral (e.g., crops, livestock, fisheries, aquaculture, and forestry) and multiobjective (e.g., economic, social, and environmental) policies and instruments, identifying possible synergies as well as balancing trade-offs between them. At the core of that approach are five principles: improved efficiency of the resources used in food and agriculture; direct action to conserve, protect, and enhance natural resources; protection and improvement of rural livelihoods, equity, and social well-being; enhanced resilience of people, communities, and ecosystems; and responsible and effective governance mechanisms.

In recent years, productivity and sustainability of agriculture and food systems have received increased attention at the global level. In 2015, world leaders adopted Sustainable Development Goals (SDGs) to be achieved by 2030, and 16 of the 17 SDGs have strong linkage with sustainable food and agriculture. Several other global initiatives (the Addis Ababa Action Agenda on financing for development, the 2015 Paris Agreement on coordinating action to address climate change, the Sendai Framework for Disaster Risk

Reduction, and others) also have strong connections to productivity and sustainability of agriculture and food systems.

While these developments at the global level are both important and welcome, policy coherence and coordinating efforts at the country level are more critical because sustainable food and agriculture must be achieved by the countries themselves. A holistic and integrated approach at the country level that aligns national development goals with global goals increases policy coherence and synergies across relevant ministries and agencies, enhances on- and off-farm employment and income opportunities, and raises investment in food and agriculture that would address many of the aforementioned challenges. Of particular use would be specific actions aimed at maximizing resource use efficiency, reducing food loss and waste, converting waste to wealth through reuse, and protecting, conserving, and sustainably using key natural resources that underpin the entire food system. However, no country has yet implemented such a system.

This book is the first effort to point the pathway toward more sustainable agriculture and food systems through an integrated and cross-sectoral approach. Addressing the present and future challenges of the agriculture and food systems requires better understanding of the positive and negative impacts of the agricultural sectors (crop, livestock, fisheries, aquaculture, and forestry) on the world's social, economic, and environmental themes. It also requires an understanding of the drivers of change, and linkages between the rural and urban economies. Many trade-offs emerge from production to consumption with impacts on efficiency, sustainability, and inclusiveness, and they must be balanced with policies that promote an integrated approach. Designing systems requires knowledge and experience with issues surrounding the current global food systems and the capacity to look at their future.

Consequently, this book is based on collective knowledge and experience of 78 highly knowledgeable and experienced scientists, teachers, policy experts, and leaders from 30 organizations, including universities and public, private, and international institutions/organizations around the world. The lead authors of the five sections (Rob Vos and Shenggen Fan for Section I; Jules Pretty and Zareen Bharucha for Section II; Henning Steinfeld and Tim Robinson for Section III; Leslie Lipper and Jeroen Dijkman for Section IV; and Clayton Campanhola, Kostas Stamoulis, and Shivaji Pandey for Section V) have used their years of work and experience with food systems around the world to refine the initially proposed outlines and identify additional contributors to their sections. Under such leadership and effort, section I aims at increasing understanding of factors, issues, and challenges that impact on the productivity and sustainability of the world's agriculture and food systems now and will continue to do so into the 21st century. Section II describes policies, technologies, approaches, and systems that have proven to be successful in the recent past or are being tested and promoted for addressing many of the challenges faced in different parts of the world. Section III considers the growing conflict between escalating human demand for food and other benefits, with resource degradation and scarcity, analyzes how different agriculture and food systems respond to this conflict, and suggests cross-cutting approaches for coping with their complexity and diversity. Section IV describes the importance of identifying and balancing trade-offs that occur because of tension between natural and social systems, as discussed in Section III, presents a general approach to implementing sustainable food and agriculture and provides

examples of successful implementation of the approach at global and national levels. Finally, Section V focuses on research and innovation, policies and incentives, resource mobilization, and governance and institutions—the four areas considered most critical to the meaningful and needed structural transformations. The section ends with a set of recommendations that, if adapted and adopted at global, national, and local levels, would improve productivity and sustainability of agriculture and food systems.

This book is aimed at policymakers, agricultural research and extension professionals, development practitioners, and students and teachers of biological, social, and agricultural science. We hope it will inform, as well as stimulate and motivate them to consult the lead authors, contributing authors, and relevant references for additional information. Finally, it is our fervent expectation that this book will help the world transition toward more productive and sustainable agriculture and food systems for the benefit of present and future generations.

Clayton Campanhola and Shivaji Pandey

The Food and Agriculture Organization of the United Nations (FAO), Rome, Italy

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Acronyms

AAC	African Agricultural Capital Limited
AFOLU	agriculture, forestry, and land use
AFS	agriculture and food systems
AIS	agricultural innovation system
AMR	antimicrobial resistance
AR4D	agricultural research for development
ARI	agricultural research intensity
CAAS	Chinese Academy of Agricultural Sciences
CGIAR	Consultative Group for International Agricultural Research
CFS	Committee on World Food Security
CRP	CGIAR Research Program
EAP	East Asia and Pacific
FAO	Food and Agriculture Organization of the United Nations
FDI	foreign direct investment
FFS	farmer field schools
GAFSP	Global Agriculture and Food Security Program
GDP	gross domestic product
GHG	greenhouse gases
GREL	Ghana Rubber Estates Limited
HANPP	human appropriation of net primary production
HICs	high-income countries
HLPE	high-level panel of experts
ICT	information and communication technologies
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
IPBES	intergovernmental science-policy platform on biodiversity and ecosystem services
IPM	integrated pest management
LIC	low-income country
LMICs	lower middle-income countries
NGO	nongovernmental organization
ODA	official development assistance
OECD	Organisation for Economic Co-operation and Development
PGRFA	plant genetic resources for food and agriculture
PPP	purchasing power parity
R&D	research and development
SDG	Sustainable Development Goal
SES	social-ecological systems
SFA	sustainable food and agriculture
SSA	sub-Saharan Africa
TFP	total factor productivity
UNFCC	United Nations Framework Convention on Climate Change
WFP	World Food Programme
WTO	World Trade Organization

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SECTION I

FOOD AND AGRICULTURE AT A CROSSROADS

Lead Authors

Rob Vos and Shenggen Fan (International Food Policy Research Institute (IFPRI), Washington, DC, United States)

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CHAPTER

1

Food and Agricultural Systems at a Crossroads: An Overview

1.1 THE STATE OF GLOBAL FOOD AND AGRICULTURE

Over the past century, enormous progress has been made in improving human welfare worldwide. Societies have changed radically thanks to quantum leaps in technology, rapid urbanization, and innovations in production systems. Yet, conditions today are a far cry from the world "free of fear and want" envisioned by the founders of the United Nations. Amid great plenty, billions of people still face pervasive poverty, gross inequalities, joblessness, environmental degradation, disease, and deprivation. Much of humanity's progress has come at a considerable cost to the environment. The impacts of climate change are already being felt and—if left unabated—will intensify considerably in the years ahead. While globally integrated production processes have brought many benefits, challenges in regulating those processes highlight the need to steer them toward more equitable and sustainable outcomes.

Such challenges raise concerns regarding the feasibility of achieving the sustainable development goal (SDG) of ending hunger and all forms of malnutrition while making agriculture and food systems sustainable (SDG2). Are today's food and agricultural systems capable of meeting the needs of a global population that is projected to reach almost 10 billion by mid-century? Can we achieve the required production increases, even if this implies adding pressure to already dwindling land and water resources, specifically within the context of climate change?

As these challenges are strongly interrelated, addressing them in order to achieve SDG2 and other related SDGs will require a systems approach to food and agriculture. While still critical, agricultural development alone will not be enough to secure adequate food availability and stave off hunger and famine. Food systems at large will need to be sustainable in order to address multiple development challenges.

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Section I of this volume contains eight chapters addressing key questions regarding the sustainability of food and agriculture systems across various dimensions. The assessments coincide in the view that current trends and policy efforts *will inadequately* address these challenges, seriously jeopardizing prospects of achieving SDG2. Significant, transformative changes in agriculture and food systems need to occur to achieve a world without hunger and malnutrition and to protect the natural resource base required for feeding present and future generations.

1.2 FOOD AND AGRICULTURE AT A CROSSROADS: CHALLENGES AND OPPORTUNITIES

Global Trends and Challenges to Food and Agriculture Into the 21st Century

Rob Vos and Lorenzo Giovanni Bellù review some of the key global trends and challenges facing agriculture and food systems through the 21st century (Chapter 2: Global Trends and Challenges to Food and Agriculture Into the 21st Century). They start by addressing the core question of whether today's agriculture and food systems are capable of meeting the needs of a global population that is projected to reach almost 10 billion by mid-century and that may peak at more than 11 billion by the end of the century. They project that global food demand will increase by 50% between 2012 and 2050. During the preceding four decades, food production more than tripled, to the extent that current systems are likely capable of producing enough food. Moving forward, the challenges will be both different and more complicated.

With accelerating urbanization and continued income growth, especially in emerging economies, dietary preferences are shifting rapidly toward increased demand for more resource-intensive food, such as animal-sourced foods, fruits and vegetables, and processed foods. Satisfying this rising and changing demand through the currently prevalent farming and food processing systems will likely put added pressure on already scarce land, soil, and water resources and further degrade the quality of these resources. Some regions, especially tropical zones, already suffer from the adverse impacts of climate change. If left unabated, climate change will significantly slow agricultural productivity growth in the coming decades. Changing dietary patterns and food systems is a double-edged sword in terms of nutritional outcomes. They have facilitated the intake of more diversified diets and improved the nutritional status of many. However, at the same time, the increased consumption of animal-sourced food and the often too salty and sugary processed foods has given rise to the spread of overweight and obesity, which in turn are associated with a rising prevalence of noncommunicable diseases. Additionally, the ease of access to low-nutrient processed foods has also led to a further spread of people suffering from micronutrient deficiencies. Consequently, as Vos and Bellù show, ending hunger and all forms of malnutrition by 2030 (and not even by 2050) will be nothing but an elusive target if current trends continue. Hence, they argue, transformative changes to agriculture and food systems are urgently needed to feed the world sustainably.

The Demographics of Rural Poverty and Sustainable Agriculture and Rural Transformations

Population, income, and urban growth have been key drivers underlying many of the changes in food and agricultural systems and will continue to pose challenges to the sustainability of these systems for decades to come. Chapter 3, Demographic Change, Agriculture, and Rural Poverty, by James Thurlow, Paul Dorosh, and Ben Davies dwells further on these drivers to spell out key challenges for employment and poverty reduction in those regions where much of the demographic dynamics will appear: South Asia and, in particular, sub-Saharan Africa. These regions have lagged in the structural transformation of their economies and as a result will feel the weight of demographic pressures threatening future economic and social progress. Structural transformation entails workers leaving less-productive agriculture and moving to more productive industries, often in urban centers. Population growth slows with development, leading to greater dependence on capital and technology rather than on labor. This was East Asia's successful pathway. Sub-Saharan Africa is also transforming, but far less than other regions and with its own distinctive features. Africa is urbanizing, but rapid population growth means that rural populations are still expanding. African workers are leaving agriculture, albeit at a slower pace than in East Asia, and they are finding work in less-productive services rather than in manufacturing. The authors argue that this "urbanization without industrialization" raises concerns about Africa's ability to create enough jobs for its urban workforce and underscores the need for continued focus on rural Africa. The chapter reviews the linkages between urbanization, agriculture, and rural poverty in sub-Saharan Africa, where most of the world's poor will soon reside. It suggests that much of the economic growth and structural change that Africa enjoyed over the past two decades, while involving a shift out of agriculture, was in fact an expansion of downstream components of the agriculture food system. Like agriculture, many downstream activities have strong linkages to poverty reduction. Governments concerned about jobs and poverty will need to raise productivity not only in agriculture, but—as also assessed in Chapter 9, Changing Food Systems: Implications for Food Security and Nutrition—also throughout the food system. Since many downstream processing and trading activities take place in towns and cities, promoting future poverty reduction will require greater alignment between agricultural and urban policies. Demographic change and rural-urban linkages will continue to be powerful drivers of global poverty reduction, but ensuring inclusive transformation will require broader development perspectives and policy coordination.

Climate Change, Agriculture, and Food Security: Impacts and the Potential for Adaptation and Mitigation

Climate change is a significant and growing threat to food security—already affecting vulnerable populations in many developing countries and expected to affect an ever-increasing number of people in more areas in the future unless decisive actions are taken at once. Chapter 4, Climate Change, Agriculture and Food Security: Impacts and the Potential for Adaptation and Mitigation, by Keith Wiebe, Sherman Robinson, and Andrea Cattaneo reviews research on climate change and its impacts on agriculture and food

security at global, regional, and national scales. They summarize the International Food Policy Research Institute's latest long-term projections of the impacts of climate change on agricultural area, yields, production, consumption, prices, and trade for major crop and livestock commodities, as well as their implications for food security.

A wide range of available sustainable intensification technologies and practices can help farmers both adapt to and mitigate climate change impacts. Such technologies can also help reduce food insecurity. The model-based scenario analyses presented in the chapter suggest that under a wetter and hotter climate scenario the number of food-insecure people in developing countries could be reduced in 2050 by 12% (or almost 124 million people) if nitrogen-efficient crop varieties were widely in use; by 9% (91 million people) if no-till farming were more widely adopted; and by 8% (80 million people) if heat-tolerant crop varieties or precision agriculture were adopted.

While such innovations show considerable potential, realizing these gains requires not only increased investment in research, but also measures to overcome barriers to more widespread adoption of innovations in technologies and management practices. Wiebe, Robinson, and Cattaneo argue that the impacts of climate change on agricultural producers and consumers, and the ability to adapt and mitigate those impacts, depend critically on socioeconomic factors and conditions as much as on biophysical processes. The challenges of climate change and food security are complicated by the extent to which they emerge from the individual and collective actions of some 570 million farm households and over 7 billion consumers worldwide. The global public good nature of climate change means that mitigation requires coordinated collective action in order to succeed. Meeting the challenges of climate change adaptation and mitigation equitably and effectively thus requires well-informed, evidence-based global and local policy action to ensure the appropriate enabling environments.

Water Scarcity and Challenges to Food Security

Water availability for agriculture will become a growing constraint in areas that use a high proportion of their water resources, exposing systems to high environmental and social stress, and limiting the potential for expanding irrigated areas. In fact, the rate of expansion of land under irrigation is already slowing substantially. Meredith Giordano, Jennie Barron, and Olcay Ünver assess in Chapter 5, Water scarcity and Challenges for Smallholder Agriculture, the key global challenges to adequacy of water availability and how increasing scarcity and competition for water resources are affecting agricultural productivity, especially that of smallholder producers in Africa and Asia. They also provide evidence on the viability of alternative, improved practices of sustainable water management adapted to the needs of smallholder farmers.

Severe water scarcity is a main challenge for the many smallholders in Africa and Asia. This challenge is rooted in physical limitations to available water resources and institutional obstacles preventing smallholders from accessing available supplies. Promising agricultural water management investment options exist to address the water scarcity challenge, and the authors provide evidence of four promising opportunities tailored to different water scarcity contexts. Two of the business models focus on improving access to

water resources, as well as to agricultural water management technologies, by enhancing the number and quality of irrigation service providers and increasing investments in water storage. The other two models look beyond the water sector itself to identify smart solar solutions that will improve access to water in energy-poor environments, such as in rural Ethiopia, and support the sustainable use of sparse groundwater resources, such as in western India, through incentives to the energy sector.

Forests, Land-Use Change, and Challenges to Climate Stability and Food Security

Agriculture is a significant contributor to deforestation, biodiversity loss, and greenhouse gas emissions. However, agricultural productivity is most likely to suffer adverse consequences of climate change. In Chapter 6, Forests, Land Use, and Challenges to Climate Stability and Food Security, Terry Sunderland and Dominic Rowland examine the tensions between agricultural development, food security, and forest preservation. They distinguish three roles and functions of forests. The first is the provisioning function, as a direct source of food and income and as a means for agroforestry. The second is protective, in the sense of ecosystem service provision. The third is the ecosystem restorative capacity of forests, which can be leveraged through increasing the availability of trees and forests in agricultural landscapes. Such contributions include climate change mitigation via sequestration and the restoration of degraded agricultural land. Together with these three functions, the authors raise three key questions to be addressed if trade-offs between agricultural growth, food security, and forest preservation are to be overcome: How do we increase food production on existing agricultural land while reducing environmental degradation? How do we reduce the environmental degradation and loss of ecosystem services as well as important sources of wild food and income resulting from agricultural expansion into natural habitats? How do we restore degraded, unproductive, and abandoned agricultural land and natural habitats?

The authors argue that forests and trees are an essential part of the solution to all three questions. Trees in agricultural landscapes can simultaneously increase agricultural productivity and mitigate against environmental degradation. Judicious landscape-scale land-use planning that incorporates trees and forests into productive landscapes can simultaneously conserve forests and protect the ecosystem services upon which agricultural production depends. At the same time, reforestation and regeneration of forests can restore degraded land and provide new productive landscapes on abandoned or degraded land.

Land and Water Governance, Poverty, and Sustainability

Water, land, and soils are essential resources that are fundamental to food security and for alleviating hunger and poverty. How these resources are managed are critical to the sustainability of agriculture and the natural resource base. However, global population growth, changing diets, and a changing climate have together created concerns that demand may soon outstrip available resources if we continue to use them with the current intensity and production practices. Technological innovation can help to increase production and reduce demand, but most analysts now accept that the greatest benefits will

come from improving the way we use and manage existing resources. Most population growth is expected to occur in developing countries where resource governance tends to be weak and fragmented, and where people are least able to cope with the challenges accompanying sustainable usage and conservation of these resources. Chapter 7, Land and Water Governance, Poverty, and Sustainability, by Olcay Ünver and Eduardo Mansur analyzes current constraints in land use and soil quality. The authors show how the problems of land tenure and the failure to integrally manage water, land, and soil resources are conspiring against the sustainable use of those resources. The chapter proposes a fundamental reform of governance mechanisms oriented at greater coordination across those dealing with land, water, and soils.

Biodiversity and Ecosystem Services

Severe biodiversity loss is caused by ongoing deforestation, simplification of agricultural landscapes, intensive use of natural resources, and impacts of climate change. Plant genetic resources for food and agriculture form the basis of food security and consist of diversity of seeds and planting material of traditional varieties and modern cultivars, crop wild relatives, and other wild plant species. Currently, only about 30 crops provide 95% of human food energy needs, four of which—rice, wheat, maize, and potato—are responsible for more than 60% of our energy intake. Because of the dependence on a small number of crops for global food security, it will be crucial to maintain a high genetic diversity within these crops to deal with increasing environmental stress, and to provide farmers and researchers with opportunities to breed crops that can be cultivated under unfavorable conditions such as drought, salinity, flooding, poor soils, and extreme temperatures.

The loss of biodiversity in beneficial organisms in agricultural landscapes, such as natural predators of crop pests, pollinators, and soil microbes, due to habitat loss and toxic chemical pesticide use threatens the ability of ecosystems ability to maintain ecological functions and equilibrium among natural flora and fauna that underline the biophysical capacity of agricultural ecosystems. The conservation and sustainable use of plant genetic resources for food and agriculture and landscape biodiversity is necessary to ensure crop production and to meet the growing environmental challenges and impacts of climate change. The loss of these resources or a lack of adequate linkages between conservation and their use poses a severe threat to the world's food security in the long term.

In Chapter 8, Biodiversity and Ecosystem Services, Wei Zhang, Ehsan Dulloo, Gina Kennedy, Arwen Bailey, Harpinder Sandhu, and Ephraim Nkonya highlight the linkages between plant genetic resources for food and agriculture, dietary diversity, and natural habitats, as well as the roles of gender and community in conservation. Diversely structured landscapes play a crucial role in supporting environmental services that maintain the productivity and stability of agroecosystems. To ensure that the global food system remains environmentally sustainable and generates a rich array of nutrients for human health, farm landscapes must be diverse and serve multiple purposes. The authors emphasize the need for economic valuation of environmental services in both monetary and nonmonetary terms to assess the global cost of land degradation and loss of biodiversity and the benefits for food production systems to restore soil quality and biodiversity.

Changing Food Systems: Implications for Food Security and Nutrition

Food systems are changing, with growing reliance in many regions on global supply chains and large-scale distribution systems that both meet and fuel the changes in food demand and dietary preferences. While improving efficiency, the changing nature of food systems is also creating new challenges and concerns regarding the high calorie and low nutritional content of many food items, access of small-scale producers to viable markets, high levels of food loss and waste, incidences of food safety, animal and human health issues, and the increasing energy intensity and ecological footprint associated with the lengthening of food chains. Chapter 9, Changing Food Systems: Implications for Food Security and Nutrition, by Hanh Nguyen, Jamie Morrison, and David Neven argues that, in order to properly understand the implications of these challenges for future food security and nutrition, actions across a multitude of actors (from producers to consumers) will need to be coordinated from a food-systemwide perspective.

The authors note the accelerated change toward modern, industrial food systems in developing countries, which is being driven by rapid urban growth and strong economic expansions in recent decades. This has given rise to the notion of a growing "global middle class," whose size is projected to increase almost threefold between 2009 and 2030. With greater disposable income and increased exposure to imported foods and large-scale retailers, this global middle class is adopting radically different lifestyles and acquiring new food preferences. At the same time, however, although overall poverty has declined, the percentage of poor people living in urban areas is growing. While the food demand of the middle class in many developing country regions is increasingly being met through global supply chains and large-scale distribution systems, the urban poor still rely significantly on informal traditional markets as their primary food supply channel.

Rapid technological innovation, especially in information and communication technologies and renewable energy, has been another major driving force of food system changes. The judicious use of these technologies, both on-farm and off-farm, has shaped and will continue to shape the productivity and competitiveness of food systems. Finally, climate change and resource scarcities pose significant risks and can threaten the productive capacity and stability of food systems. In turn, food systems have contributed significantly to global greenhouse gas emissions (almost 30%) as well as to the degradation of natural resources. The authors further argue that the development from traditional to modern food systems has had mixed outcomes in terms of food security and nutrition, rural employment, and poverty reduction. On the one hand, modern food systems can enhance farmers' access to viable markets. Farmers who enter into contracts with companies enjoy formal employment opportunities, often alongside technical assistance to improve the efficiency of the production process and the quality of their produce. On the other hand, the concentration of market power to a few large-scale processors, wholesalers, and retailers who constantly seek to reduce production and transaction costs exerts huge pressure on small suppliers. Such development can work to the disadvantage of smallholders, who find it difficult to meet the requirements of large buyers for product uniformity, consistency, and regular supply.

The dramatic pace of food system changes over the past decades has brought about complex interactions with, as mentioned, mixed outcomes for food security and the

sustainability of agriculture and food systems. Many trade-offs have emerged between food system efficiency, sustainability, and inclusiveness. The authors argue that direct interventions to address such trade-offs in one area of the system may risk exacerbating problems in another. Therefore, they argue that agriculture and food policies should take a holistic system-wide approach to be effective.

1.3 GLOBAL CHALLENGES, GLOBAL RESPONSES

The international community has recognized these challenges along with the interdependencies between them. The 2030 Agenda for Sustainable Development (2030 Agenda) provides a compelling and ambitious vision for transformative change to put economies, and agriculture and food systems with it, on a sustainable footing. SDG2 explicitly aims at ending hunger, achieving food security and improving nutrition, and promoting sustainable agriculture simultaneously by 2030. The 2030 Agenda and the Addis Ababa Action Agenda on financing for development specifically call on all countries to pursue policy coherence and establish enabling environments for sustainable development at all levels and by all actors (SDG17). The 2015 Paris Agreement on climate change reflects a global commitment for concerted actions to address the perils of climate change. The Sendai Framework for Disaster Risk Reduction also gives priority to agriculture sectors.

Despite these promising international frameworks for action, achieving policy coherence will be challenging. The 2030 Agenda and other related global agreements stress the interdependence of the challenges they must address. They also recognize the need to integrate different actions to achieve linked objectives and that doing so will pose new technical demands on policymakers, at all levels, as well as new demands on institutional arrangements and coordination at various levels of governance.

To meet these demands, more and better data and research will be needed. For instance, existing evidence on the degree and ways in which climate change is affecting agriculture, food, and nutrient availability in different settings is still surrounded by a fair amount of uncertainty and there are still many unknowns. Likewise, policies would need to take new, as yet, untested directions requiring new data collection and impact assessments to monitor their effectiveness and to provide the necessary accountability. Moreover, research will be critical to understand how food systems can address emerging social issues, including various forms of inequality, youth unemployment, migration, and conflict. Additionally, it is critical to better understand how the accelerated pace of technological innovation in information and communication technologies and biotechnologies, for example, can be made to create innovations to help make agriculture and food systems sustainable.

The purpose of Section I of this volume is not to present a menu of solutions, but rather to increase understanding of the nature of the challenges that agriculture and food systems now face and will be facing throughout the 21st century.