

# SUSTAINABLE FOOD SYSTEMS FOR FOOD SECURITY

Need for combination of local  
and global approaches

A. Thomas, A. Alpha, A. Barczak, N. Zakhia-Rozis, editors





# Sustainable food systems for food security

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and global approaches

Alban Thomas, Arlène Alpha, Aleksandra Barczak, Nadine  
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# Foreword

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Food systems, understood as all activities and actors connecting food production, transportation and storage, processing and catering, distribution, preparation, consumption, and waste and resource management, as well as agricultural input suppliers and the associated regulatory institutions, represent a huge share of human activities and livelihoods. They are also at the centre of humanity's main challenges: climate change, human and environmental health, biodiversity erosion, equitable human development and, naturally, food and nutrition security.

Food and nutrition security is therefore a major area of research in food, agriculture and the environment. Achieving global food security involves identifying ways to transform our food systems to provide sustainable, healthy and accessible food to all human beings, who will number nearly 10 billion by around 2050. New paths forward should encompass all dimensions of food security: availability of agricultural and food products, access to and utilization of food, and stability in the food supply. Designing and accompanying agricultural and food system transitions and achieving global food security covers an incredibly large set of issues, scientific disciplines and scales of analysis. It is therefore not surprising that CIRAD and INRAE, France's two main agricultural research institutions, have taken up a joint research programme on food security. GloFoodS (Transitions for Global Food Security) was launched in 2014 as a 'metaprogramme', an INRAE initiative to address a specific challenge with an interdisciplinary perspective, a dedicated budget and a roadmap shared by stakeholders. But what truly made GloFoodS original was the idea of developing a metaprogramme as a joint CIRAD-INRAE initiative for the first time and bringing together the multidisciplinary scientific skills of INRAE (then INRA) and CIRAD to explore the four dimensions of food security, while also incorporating the public policy dimension.

The GloFoodS flagship programme (2014 to 2020) was a unique experience in joint research management for CIRAD and INRAE. It was motivated by the strategic importance of food security as a research subject in our strategic plans, as well as by the need to gain visibility in international forums on global issues involving food security governance. Beyond the rather conventional analysis of the balance between agricultural supply and food demand, along with the role of food security governance models, GloFoodS added five more areas of research: trends and variability in crop and animal yields; production potential of additional land; innovations in products, processes and organizational approaches to limit food waste; determinants of nutritional transitions and their health and environmental impacts; and links between household access to food and poverty.

When the metaprogramme came to a close at the end of 2020, the scientific leaders behind GloFoodS proposed a series of outreach events, including a final programme workshop. They also formed a scientific committee to edit a volume of contributed chapters from research findings obtained with the support of the GloFoodS programme. As readers can see from the list of chapters, the wide range of topics and scientific fields and disciplines is consistent with the scope of our initial objective when GloFoodS was launched by our two institutions. The metaprogramme covered

a variety of areas and challenges, ranging from food security governance to the impact of food and nutrition transitions on agricultural systems and practices, the global balance between food production and availability, the challenge of reducing food waste by optimizing food processes, the drivers of the agroecological transition in developing and industrial countries, and the relationships between food security, access to land and natural resources at the local level.

By enhancing the joint provision of scientific knowledge on issues related to food security by CIRAD and INRAE, GloFoodS has also contributed to strengthening the position of our research institutions in public debates and international initiatives on food security. It is clear that global food security will remain on the CIRAD and INRAE research agenda for some time, as demonstrated by our priorities and objectives (INRAE 2030 Roadmap, CIRAD Scientific and partnership strategy 2019–2023).

For INRAE, this is particularly true for one of its five scientific priorities detailed in the INRAE 2030 strategic document (‘INRAE2030 – Building a sustainable future through shared science and innovation’): ‘Accelerating agroecological and food transitions while answering socioeconomic challenges’. Within this general priority, a first proposal is to strengthen our understanding of transition processes and food security challenges, such as by modelling and evaluating foresight scenarios of changes in food supply and demand at the global scale; analysing the variety of food systems with regard to their autonomy and resilience at various scales; and analysing trends in agricultural structures and factors of production, including land and labour, their autonomy with respect to public support policies and their vulnerability to global risks (climate, markets, etc.). A second proposal concerns the design of healthy and sustainable food systems available to all. Examples of specific objectives include a more comprehensive understanding of the factors of changes in food systems at the global and local scales, and the evaluation of the health, economic, social and environmental impacts of such changes.

For CIRAD, which works specifically on food systems in developing countries, four out of six of the key thematic fields in its ‘Scientific partnership and strategy objectives’ (OSSP2 covering the period 2019–2024) are directly linked to food systems and GloFoodS research questions: engineering the agro-ecological transition, using territories as levers for sustainable and inclusive development, supporting the transition to more sustainable and inclusive food systems; and helping farming systems in the Global South adapt to climate change. CIRAD is convinced that food systems must change to be able to produce more and better, address all agroecological principles, and ultimately improve food security, the core component of the development-health-climate-environment nexus.

The upcoming United Nations Food Systems Summit (UNFSS) is a strong call to action where leaders expects bold moves and disruptive decisions. The world’s scientific communities must mobilize. Our research institutions have a duty to produce scientific knowledge for which international partnerships are essential, issue guidance for decision-makers, and ultimately bring about real change. We hope readers of the English version of this book (the French version is forthcoming) will be interested in learning more about the scientific communities at CIRAD and INRAE that work on the numerous dimensions of food security and will gain new insights on the topic of food security.

*Michel Eddi, former CEO of CIRAD and Philippe Mauguin, CEO of INRAE*

# Preface

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Food and nutritional security refers to the challenge of providing sustainable, healthy and accessible food to all human beings. It comprises four dimensions covering overlapping issues: availability, utilization, accessibility and stability. This tremendous challenge requires a transformation of the world's food systems and the mobilization of all stakeholders and policymakers based on knowledge and scientific evidence. There is a clear need for intersectoral and more integrated knowledge, which is why two major French agricultural research organizations, CIRAD and INRA (which became INRAE in 2020), led an ambitious interdisciplinary flagship programme between 2014 and 2020 on the transitions for global food security: the GloFoodS metaprogramme. This metaprogramme called upon the multidisciplinary scientific skills and the international experience of both institutions to explore the balance and discrepancies between agricultural supply and food needs and the role of governance modes of food security, while accounting for the potential impact of global change. It operated on a variety of scales, from the global level all the way down to the household level. It funded 45 research projects (involving 35 PhD doctoral students) over the 2014–2020 period, mostly with international academic partners and often with stakeholder participation in more than 25 countries, covering a wide range of topics informing food and nutrition security in response to four overarching questions: 1) How does the evolution of agricultural production affect households' dietary transitions and access to food? 2) How does the evolution of agricultural production interact with the efficiency and sustainability of food systems, especially losses and waste? 3) How does governance affect agricultural production systems and land use? 4) How do dietary transitions affect the balance of food availability, agricultural production systems and land use?

The GloFoodS metaprogramme contributed to international research on food security with regard to several dimensions. First, it combined original approaches in agronomy, environmental sciences, nutrition, economics and sociology, among other disciplines, while also adopting a global viewpoint. Second, it connected global change components (climate change and global change, management of natural resources) with nutritional transitions of populations and the impact of those transitions on agrifood chains. Such a global positioning was naturally combined with local approaches so as to compare regional outcomes of global scenarios with observations at a smaller geographical scale. The GloFoodS metaprogramme therefore addressed questions related to agricultural sciences, livestock systems, global modelling, land-use changes, economic and sociological patterns in rural areas, agrifood technologies, nutrition and food security governance. Finally, GloFoodS aimed to provide original research at the interface of food security challenges that are often highly specialized in terms of fields and disciplines.

This book proposes a selection of results that draw upon research projects funded by GloFoodS. The findings address the issue of governance of food systems, the links between agricultural supply and food and nutritional needs, agroecological innovations and dietary diversity, the challenges of innovative processing of

high-quality foods, agroecology and resilient food value chains, and local resource management as a driver of food security.

Conducting the GloFoodS metaprogramme over this period was a formidable scientific and human challenge for us and for the scientific community involved at CIRAD and INRAE. We hope that this book will be useful to readers interested in transitions towards global food security, and that the enthusiasm with which we accompanied the participating researchers will be reflected throughout its pages.

*Alban Thomas, INRAE, and Etienne Hainzelin, CIRAD,  
co-directors of GloFoodS*

# Introduction

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Alban Thomas, Arlène Alpha, Aleksandra Barczak,  
Nadine Zakhia-Rozis

World food security is consistently associated with the challenge of providing sustainable, healthy and accessible food to all human beings, whose total population is expected to reach between nine and ten billion around the year 2050. The definition of food security adopted at the World Food Summit in 1996 was the following: ‘Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life’. From this definition, as well as its shorter version (‘adequate access to food for all people at all times for an active, healthy life’), four dimensions of food security are generally accepted: availability, accessibility, utilization and stability. These dimensions encompass specific or overlapping issues.

First, availability of food depends on the capability of the world’s food systems to produce food at the necessary quantity and quality demanded. The second dimension concerns access to food and is related to the issues of poverty and social inequalities that limit access to a balanced diet for a large part of world’s population. Third, final food consumption addresses the issue of ongoing diet transitions, the consequences of under- and overnutrition and the resulting double burden. Fourth, most stages of food systems (crops and livestock, agrifood chain, retail, etc.) must deal with volatility and risk in markets and in the supply chain, resulting in instability of market prices. Moreover, each of these four dimensions is impacted by global changes that are already at play, especially climate change but also the depletion or degradation of natural resources and demographic and energy transitions.

Food security becomes even more complex when it comes to the scale of analysis, the type of actors involved in food systems and the geographical areas studied. More precisely, the concept is pertinent at the global scale (how do we feed the world in the coming decades?) and the local scale (how do we design more sustainable food systems at the community level?), as well as for various settings (urban food systems and the management of urban solid waste, sustainable livelihoods in rural areas). Having access to a sufficient quantity of healthy food is of course a major concern in developing countries, but it is also an issue for vulnerable population segments in developed countries. On the producer side, improving agricultural cropping and livestock systems is also relevant for a wide range of geographical regions, to make

them less detrimental to the environment and ensure they do not jeopardize the availability of natural resources for future generations.

From the brief exposition above of the formidable challenges implied by the food security objective and its implications for food system organization and performance in their agricultural production, food processing, distribution and final consumption stages, it is clear that food security requires a significant interdisciplinary drive.

This book presents a collection of chapters authored by researchers from CIRAD and INRAE, who were principal investigators or contributors to research projects funded by the GloFoodS metaprogramme from 2014 to 2020. While these chapters do not form an exhaustive list of all topics, approaches, or global or regional challenges of food security, they are nevertheless representative of interdisciplinary research conducted with the support of GloFoodS. Compared with other published collective contributions on food security, this book presents research results corresponding to, in our view, a wider scope of disciplines and dimensions of food security, while providing recent research results. Another source of originality lies in the variety of scales of analysis as well as in the combination of local and global approaches to food security.

The book is divided into six sections of two to three chapters each. The first section addresses the issue of food system governance.

Chapter 1 by Arlène Alpha, Antoine Bernard de Raymond, Sandrine Fréguin-Gresh and Allison Loconto uses food security governance as an analytical framework to show that the governing effects of food security discourse might be more pervasive than structured debates and formal policies. The authors illustrate the operationality of their governance analytical framework to reveal the consequences of framing food security in a particular way and applying instruments that put those frames into practice through three case studies: a national food programme in Nicaragua, the resilience agenda and its operationalization in the Sahel, and land-use modelling. These case studies provide a convincing argument for the usefulness of such approaches in analysing food security where ostensibly neutral instruments have the power to constrain the possibilities for action, which in turn shape actors' behaviours.

Chapter 2 by Céline Bignebat, Romain Melot, Paule Moustier, Emmanuel Raynaud and Guillaume Soullier explores the governance of land and food value chains and its impact on populations' livelihoods. They acknowledge that the literature increasingly accounts for the role of farmers' livelihoods in fostering food security, including access to land and markets, public policies, the actions of private macro-stakeholders in land transactions and the trade of agricultural products, as well as land governance associated with value chain governance. Case studies combine territorial governance with value chain governance through agribusinesses (Senegal), analyse the development of an industrial zone driven by public investors (Morocco) and detail local levers for the regulation of land use (France).

The second section concerns the links between agricultural supply and food and nutritional needs.

Chapter 3 by Sophie Drogué, Sandrine Costa, Michel Simioni, Viola Lamani, Marie-Josèphe Amiot and Caroline Méjean addresses the nutrition transition through food supply and demand using cross-perspective approaches in economics,

management and nutrition. The authors consider different contexts of nutrition transition to explore global changes (including the dynamics of available food supply and urbanization) and societal changes that generate dietary shifts. This chapter also studies some of the levers to curb nutrition transition centred on the perceptions and beliefs of consumers and their socioeconomic status. The first case study looks at the nutritional quality of food imports to the French West Indies, with the identification of socio-economic determinants of food demand, in a context where food supply is highly dependent on imports. The second case study is about socio-demographic determinants of nutrition transition in Vietnam, taking into account the changes in consumer behaviours and eating habits within the studied population.

Chapter 4 by David Makowski, Rotem Zelingher and Christophe Gouel explores the origins of shocks in agricultural production and their impacts on market prices of agricultural commodities. Using a literature review on crop production shocks, the authors identify the major factors determining such shocks to propose a hierarchy of the factors with the greatest impact. They also show that these factors are often interdependent, making crop yield forecasting difficult. Based on recent research projects, they show the potential of machine learning and probabilistic models to open a new avenue for predicting production shocks and their impacts on agricultural prices. This potential is connected to the development of open access databases and recent powerful algorithms. Finally, the authors discuss the economic mechanisms that link seasonal production forecasts with market impacts, and show how improving production forecasts could reduce price volatility.

Chapter 5 by Patrice Dumas, Agneta Forslund and Chantal Le Mouël explores the role of modelling frameworks to represent food diets and land-use change at a global scale. Starting with the observation that existing studies report very different results on the extent of the environmental impacts of food diets at the global scale, the authors advocate for more transparency when reporting simulation results of identical scenarios obtained from several different models. Their chapter points out the main mechanisms involved in the various models and emphasizes the extent to which these mechanisms explain the divergent results, hence contributing to clarify the debates. The authors focus on land-use change impacts caused by diet changes, and they simulate four contrasting diets with three models based on different modelling frameworks, including a biomass balance model, to widen the spectrum of the modelling frameworks considered.

The third section deals with agroecological innovations leading to dietary diversity.

Chapter 6 by Sandrine Fréguin-Gresh, Danièle Clavel, Hélène Guétat-Bernard, Geneviève Cortès, Valentina Banoviez Urrutia and Sandrine Dury concerns the valuation of the role of women in food and nutrition security. Although the role of women in food-related activities is widely recognized, few studies document the role of gender in agricultural and food systems or the relationship between gender and food and nutritional security. Based on a cross-cutting analysis of two case studies (Senegal and Nicaragua), the authors address the roles played by women in ensuring access to food for their households, including through agroecological gardens, the way these roles are maintained or reconfigured over time, and the way women negotiate spaces for action within productive and domestic spaces in order to guarantee household food security.



Chapter 7 by Ludovic Temple, Eric Malézieux, Denis Gautier, Christine Aubry, Jeanne Pourias, Raul Puente Asuero and Hubert de Bon deals with agroecological innovations, food and nutrition security and food safety for small farmers, with African-European perspectives. The authors address the question of the direct or indirect contributions of agroecological innovations in the improvement of availability and accessibility of high-quality food products. This issue of quality (encompassing nutritional, health and organoleptic dimensions) concerns farmers and practitioners of various forms of urban agriculture who want to strengthen their food security. The chapter examines the links between farming methods and dietary diversity through a cross-analysis of results on three contrasting case studies in Africa and Europe, analysing the diversity of these links, the methods used and the obstacles encountered.

The fourth section addresses the challenges of innovative processing of high-quality foods

Chapter 8 by Alain Kondjoyan, Valérie Guillard, Pierre-Sylvain Mirade, Thierry Goli, Antoine Collignan, Elodie Arnaud, Sandrine Costa, Nathalie Gontard and Nadine Zakhia-Rozis covers the issue of food loss and waste reduction in meat and fruit chains, and how food engineering could be a solution. The authors focus on the decrease in food quantity and quality at processing, distribution and consumption stages due to a lack of adequate processing and preservation technologies, and possibly a poor grasp of these technologies. They explore how the impact of processing technologies can be quantified in terms of mitigation of food loss and waste in meat and fresh fruits chains, such as by extending a product's shelf life and developing innovative processing and preservation technologies. They propose ideas to further reduce losses in these value chains through well-optimized processing and preservation technologies, using a generic food engineering approach.

Chapter 9 by Sylvain Rafflegeau, Germain Kansci and Claude Genot explores artisanal palm oil food chains in Cameroon, from quality design to consumption. The chapter aims to understand the links between the physicochemical and nutritional quality and production conditions of artisanal red palm oil from South Cameroon, and to identify the determinants of consumer choice for specific culinary applications. The authors relate the analytical quality characteristics of artisanal red palm oils to production conditions, and use field surveys to represent marketing and distribution channels of red palm oil from the industrial and artisanal producers to Yaoundé markets. Their analysis extends to the perception of product quality by consumers and the identification of various usages of red palm oil in local foods. Finally, the chapter provides a prospective analysis of artisanal production and artisanal and industrial consumption.

The fifth section looks at agroecology and resilient food value chains.

Chapter 10 by Geneviève Teil and Sylvie Lardon concerns the socio-economic and geographical perspectives on diversity, identity and resilience in the agroecological transition. The authors consider the concept of resilience as the result of a processing activity that relies on know-how, collective actions and methods of coordination between stakeholders. They propose a multidisciplinary perspective, combining socio-economics and geography, with examples from France, Italy and Brazil to show how actors use hybridizing modes of production, commercialization



and multi-actor interactions to differentiate themselves. The authors discuss the way hybridization allows for sustainable farming and food activities, while aligning with the individual and collective strategies of the actors, hence contributing to territorial development dynamics.

Chapter 11 by Éric Vall, Claire Aubron, Stéphane Ingrand, Marie-Odile Nozières-Petit, Mathieu Vigne, Marie Dervillé, Eric Sodr  and Charles-Henri Moulin addresses the leveraging of agroecology to improve milk production and marketing. The authors propose an original approach of agroecological transition, based on case studies focusing on low input or agropastoral milk production systems, predominantly family run, in Burkina Faso, India and France. They consider agroecology as a means of increasing demand for dairy products while accounting for the sustainability of natural resources and ecosystems. The chapter reviews the place of agroecology in each situation from the perspective of the FAO framework and discusses the remaining challenges regarding the mitigation of environmental impacts and the inclusive governance mechanisms for production and distribution channels in the face of market deregulation.

Section 6 is concerned with local resource management as a driver of food security.

Chapter 12 by R mi Cardinael, Olivier Deheuv s, Louise Leroux, Julie Subervie, Akiko Suwa-Eisenmann, C cile Bessou, Emmanuelle Bouquet, Thibault Catry, Regis Chikowo, Marc Corbeels, Gabriela Demarchi, Abdoul Aziz Diouf, Gati n Falconnier, Ndeye Fatou Faye, J r mie Gignoux, Christ le Icard-Verni re, Camille Jahel, Pamela Katic, Fran ois Libois, Sabine Mercier, Claire Mouquet-Rivier, Talent Namatsheve, Andr ea Renk, Ninon Sirdey, Isabelle Tritsch and Eric Verger explores the diversification strategies regarding food security and natural resources. The chapter deals jointly with two major issues faced by rural households in tropical areas: the conservation of natural resources and food security. The trade-off between profitability and sustainability underlying technical solutions to these issues is analysed through five case studies centred on diversification strategies: agroforestry in Senegal, cocoa-based agroforestry in the Peruvian Amazon, cereal-cowpea intercropping in Zimbabwe and sub-Saharan Africa, perennial palm oil monoculture in Indonesia, and extensive cattle production in the Brazilian Amazon forest.

Chapter 13 by Jean-Daniel Cesaro, Guillaume Duteurtre, St phane Guilbert and Nadine Zakhia-Rozis addresses the issue of managing urban food waste through the circular economy. The authors identify possible synergies within the food system between agriculture and cities to make food waste management more efficient. From a multi-partner and multi-sector perspective accounting for upstream and downstream sectors and the corresponding stakeholders, agriculture could be a solution for managing urban food waste. The chapter follows the production and recycling of food waste at different steps of the food system, i.e., in wholesale and retail markets, stores, restaurants and households. To show that a circular economy based on food waste valorization already exists around the world, with constraints due to sanitary regulations, the authors consider case studies on the cities of Montpellier, Chicago, Antananarivo, Dakar and Hanoi.

Chapter 14 by Perrine Burnod, Angel Avad , Paula Fernandes, Fr d ric Feder, Christine Aubry, Thibault Nordey, Laurence Defrise, Djibril Djigal, Audrey Jolivot, St phane Dupuy, Komi Assigbets , H l ne David-Benz, Coline Perrin and Val rie

Andriamanga examines challenges and innovations towards food security associated with market gardening in African cities. The authors study the effective contribution of intra- and peri-urban market gardening to urban food security, the way vegetable production evolves in a context of land competition, the role of social pressure in reducing environmental effects, and the technical and institutional innovations to reduce the use of inputs harmful to the environment and health. The chapter relies on case studies of market gardening at different scales – territory level in Madagascar, farm level in southern Benin and plot level in Tanzania and Senegal – and it combines different disciplines (economics, geography, agronomy, etc.) and methodologies (analysis of satellite images, quantitative and qualitative surveys, analysis of value chains, agronomic trials at experimental stations and on farms, etc.).

This book should appeal to readers interested in the ongoing transition towards more sustainable and healthier food systems at local, national and international scales. While researchers involved in the many dimensions of food security are a natural target readership for this book, we hope that a larger audience such as students and experts in national and international institutions as well as decision makers, civil society and other stakeholders will also benefit from these contributions.

We thank all the contributors to the book chapters, who participated in this ambitious exercise of summarizing years of research from GloFoodS projects, while also detailing the state of the art in their areas of interest and scientific prospects for future research. The chapters were carefully reviewed by scientists, both internal and external to the GloFoodS programme, whose expertise significantly contributed to the overall consistency and quality of these chapters. We would like to extend a special thanks to Marie-Josèphe Amiot, Anthony Fardet, Etienne Hainzelin, Pierre Gasselin, Eric Malézieux and Bertrand Schmitt. Finally, the editing and publishing team at Quae provided invaluable assistance in the preparation of this book. In particular, we thank Christelle Fontaine and Teri Jones-Villeneuve for having accompanied the editors throughout the publication process for this book.

## Section I

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# Governance of food systems

