Mohamed Behnassi · Mirza Barjees Baig ·
Mohamed Taher Sraïri ·
Abdlmalek A. Alsheikh ·
Ali Wafa A. Abu Risheh *Editors*

Food Security and Climate-Smart Food Systems

Building Resilience for the Global South

معهد الأمير سلطان
لأبحاث البيئة والمياه والصحراء
Prince Sultan Institute for
Environmental, Water & Desert Research

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Springer

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Foreword: Reversing Climate Change and Restoring Ecosystems as Pre-requisites for a Food-Secure and Resilient Future

Climate-induced impacts and disasters such as drought, heat stress, flooding, and crop pests have led to a decline in crop yields and livestock productivity in many regions, while severely affecting the livelihood and security of vulnerable communities, including small-holder farmers. These impacts and disasters are also critically undermining water security through changes in rainfall patterns, drying-up of rivers, and receding bodies of water. Many global assessments predict that conflicts over natural resources, especially water, may be a growing cause of violent tensions in the future, leading among other implications to mass displacements within and between countries. In this broad context, environmental degradation, climate change, biodiversity loss, and resource scarcity are increasingly impacting food systems and security, thus adding urgency to our fight against poverty and disease.

Yet science and technology now exist to reverse such trends and ensure sustainability and resilience against risks. Some evolving applications have the potential to make crops more viral- and drought-resistant in a changing climate. The Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR) technology, for instance, provides an alternative approach for improving the genetic traits of plants that is easier and generally cheaper than traditional breeding techniques. Many scientific advances have produced new genes that can fortify crops to withstand natural calamities such as pests and diseases and provide higher nutritional value. Innovations

such as smart agriculture, environmental conservation, healthcare and disease prevention, big data-driven bioinformatics, and industrial biotechnology have the potential to help maintain productivity while improving human wellbeing and resilience to shocks. All these pathways can sustainably help meet the food needs of a growing global population. In the same vein, the broad elements of diverse diets, seed and crop diversity, improvements in seed and crop delivery and cultivation, and the maintenance of our agrobiodiversity must be optimized to ensure a healthy and prosperous future for the humanity. Evidence of the wisdom of such investments is strong and growing; therefore, we must continue to invest in in order to enhance the sustainability of food systems, thus meeting a myriad of Sustainable Development Goals.

At the same time as we modernize, we must support local and traditional knowledge systems, such as those related to sustainable farming. Among the features of this preservation are enlightened agriculture and trade policies, intellectual property rights on the conservation and sustainable use of biological resources, the empowerment of women as guardians of these systems, and the equitable sharing of benefits across sectors, genders, and communities. We have as well a special obligation to build a rhetorical bridge between our environment and scientific research. The vital threats of environmental degradation, climate change, and biodiversity loss are themselves nested in the drive to advance human health and wellbeing. And the effectiveness of driving human health and wellbeing is correspondingly leveraged by a continued investment in research and innovation. Our very existence sits at the nexus of not just the interdependent, transdisciplinary nature of scientific research, but in a broader context, at the intersection of nutrition, health, agriculture, economy, environment, and governance.

These investments require, however, sustained operational funding and capital support and the capacity to engage successfully with funders, governments, policymakers, and communities. Significant investment in environmental preservation and climate resilience for sustainable farming systems and food and health security should be simultaneously combined with public-private investment in basic and applied research, building access to sustainable resources, creating appropriate and inclusive legal and policy frameworks, and enhancing innovative capacity-building.

It is true that the world is continuously trying to tackle the challenges of decelerating climate change and restoring ecosystems, but the trade-offs that they require inevitably pit one country's interests against another's. We must thus make use of all possible capacities to jointly fight climate and environmental change, thus creating a liveable and secure planet for all. This challenge is not easy: reaching it depends on the contributions of all, especially highly skilled individuals from everywhere in the world, political courage and foresight, and creative, ambitious innovation.

But it *can* be done, because it *must* be done. Our ability to create a sustained future for ourselves isn't optional: it's existential.

This timely contributed volume, *Food Security and Climate-Smart Food Systems—Building Resilience for the Global South*, falls under this prospect. It aims to provide guiding inputs to the different issues highlighted above. Under the editorship of specialized and insightful scholars, the volume advocates for a

rethinking of agricultural development models through, among others, the enhancement of climate-smart practices, extension systems' innovation, and digitalization. This will help accelerate the transformational change of current food systems towards sustainability, adaptation to, and mitigation of climate change, therefore enhancing the resilience of a food-secure future. By doing this, this volume contributes to the advancement of science, knowledge, and governance settings and inspires change processes.

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Acknowledgements

This contributed volume, as a part of a series of CERES publications, is the outcome of an international cooperation between 50 authors—scientists, junior researchers, experts, and practitioners—from many countries, disciplines, and professional areas. As mentioned above, the core idea of the volume emerged upon completion of a related volume, which had as objective the identification and analysis of the main emerging challenges to food production and security in Asia, Middle-East, and Africa, especially climate risks and resource scarcity. Building on the findings and conclusions, the current volume aims at identifying and exploring the best ways to overcome such challenges and to build resilience in almost the same regions of the Global South.

I have been honored to share the editorship of this volume with my colleagues: Dr. Mirza Barjees Baig, Prince Sultan Institute for Environmental, Water, and Desert Research, King Saud University, Saudi Arabia; Dr. Mohamed Taher Sraïri, Department of Animal Production and Biotechnology and Head of the School of Agricultural Sciences, Hassan II Agronomy and Veterinary Medicine Institute, Rabat, Morocco; and Dr. Abdlmalek A. Alsheikh and Dr. Ali Wafa A. Abu Risheh, Prince Sultan Institute for Environmental, Water, and Desert Research, King Saud University (KSU), Riyadh, Saudi Arabia. I seize this opportunity to warmly thank all of them for their collaboration and support during the publishing process. Their professionalism, expertise, and intellectual capacity made the editing process an exciting and instructive experience and definitely contributed to the quality of this publication.

I would also like to seize this opportunity as well to pay tribute to all chapters' authors without whom this valuable and original publication could not have been produced. Their collaboration, reactivity, and engagement during the process were very remarkable and impressive.

The chapters published in this volume are also the result of the invaluable contribution made by peer-reviewers, who generously gave their time and energy to provide insight and expertise regarding the volume's content. On behalf of my co-editors, I would specifically like to acknowledge, with sincere and deepest thanks, the following peer-reviewers:

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About the Publishing Institutions

The Center for Environment, Human Security and Governance (CERES), Morocco

CERES, previously the North-South Center for Social Sciences (NRCS), 2008–2015, is an independent and not-for-profit research institute founded by a group of Moroccan researchers and experts in 2015 and joined by many partners worldwide. It aspires to play the role of a leading think tank in the Global South and to serve as a reference point for relevant change processes. Since its creation, CERES managed to build a robust network involving various stakeholders such as researchers, experts, Ph.D. Students, decision-makers, practitioners, and journalists from different spheres and scientific areas. These achievements are being rewarded by the invitation of CERES members to contribute to global and regional assessments and studies (especially Ipbes, Medecc, EuroMeSco, etc.) and the invitation of the Center to become a member of the MedThink 5 + 5, which aims at shaping relevant research and decision agendas in the Mediterranean Basin. The Center has organized so far five international conferences and several training/building capacity workshops, provided expertise for many institutions, and published numerous books, scientific papers, and studies which are globally distributed and recognized. These events and publications cover many emerging research areas mainly related to the human-environment nexus from a multidimensional, multiscale, interdisciplinary, and policy-making perspectives. Through its initiatives, the CERES attempts to provide expertise, to advance science and its applications, and to contribute to effective science and policy interaction.

The Prince Sultan Institute for Environmental, Water and Desert Research (PSIEWDR), King Saud University, Riyadh, Kingdom of Saudi Arabia

PSIEWDR was established in 1986 to conduct scientific research related to environmental issues and water resources. It also engages with vital issues related to the problem of aridity and the desert environment. It conducts development initiatives for the country's desert areas, particularly programs for combating desertification in the Arabian Peninsula. PSIEWDR designed and carried out two major water harvesting and storage programs, including the construction of purpose-built infrastructure, throughout the Kingdom of Saudi Arabia using novel techniques and equipment. The Institute actively applies remote sensing technologies using advanced satellite image processing systems and GIS to study the country's environment and natural resources. In 2007, the Institute published *The Space Image Atlas of the Kingdom of Saudi Arabia*, and it is currently developing *The Environmental Atlas of the Kingdom of Saudi Arabia.* The Institute has been the primary sponsor of the biennial International Conference on Water Resources and Arid Environments (ICWRAE) held in Riyadh, Saudi Arabia since 2004. The institute hosts the General Secretariat of the Prince Sultan Bin Abdulaziz International Prize for Water (PSIPW) which honors scientists all over the world for their innovative water-related research. PSIPW, in turn, has many agreements with various international water associations as well as a close partnership with the United Nations. PSIPW and the United Nations Office of Outer Space Affairs (UNOOSA) jointly produce and maintain the International Space4Water Portal, an online hub for all stakeholders involved in utilizing space technologies for water resources applications.

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About the Editors

Dr. Mohamed Behnassi is a Full Professor and Head of Public Law in French Department at the College of Law, Economics, and Social Sciences of Agadir, Ibn Zohr University, Morocco. He is a Senior Researcher of international law and politics of environment and human security. He holds a Ph.D. in International Environmental Law and Governance (2003), a MSc. in Political Sciences (1997), and a B.A. of Administration (1995) from Hassan II University of Casablanca. He obtained a Diploma in International Environmental Law and Diplomacy from the University of Eastern Finland and UNEP, 2015. He is also an Alumnus of the International Visitors Leadership Program of the Department of State, United States of America. Dr. Behnassi is currently the Founding Director of the Center for Environment, Human Security and Governance (CERES). From 2015 to 2018, he was the Director of the Research Laboratory for Territorial Governance, Human Security and Sustainability (LAGOS). Recently, he was appointed as Expert Evaluator for the National Center for Scientific and Technical Research (CNRST/Morocco), and selected twice (2019–2024) as an Assessment Scoping Expert and a Review Editor by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) and Member of the Mediterranean Experts on Climate and Environmental Change (MEDECC). He was also selected by The Intergovernmental Panel on Climate Change (IPCC) as Expert Reviewer of the 1st Order Draft of the Synthesis Report (SYR) of the IPC—VI Assessment Report (AR6). Accordingly, he was among the Lead Authors of the 1st Assessment

Report (MAR1): Climate and Environmental Change in the Mediterranean Basin - Current Situation and Risks for the Future (MEDECC, 2021). Dr. Behnassi has published considerable number of scientific papers and book chapters in addition to 20 books, including recent ones on: Social-Ecological Systems in the Era of Risks and Insecurity—Pathways to Viability and Resilience (Springer, 2021); Building Resilience for Food and Water Security Face to Climate Change and Biodiversity Decline - Perspectives from Asia, Middle-East and Africa (Springer, 2021); and Human and Environmental Security in the Era of Global Risks (Springer International Publishing, 2019). Dr. Behnassi serves as a reviewer for many global publishers (such as Routledge and Springer) and scientific journals with high impact factor. He has organized many international conferences covering the above research areas, managed many research and expertise projects, and is regularly requested to provide scientific expertise nationally and internationally. Other professional activities include social compliance auditing and consultancy by monitoring human rights at work and the sustainability of the global supply chain.

Dr. Mirza Barjees Baig is a Professor at the Prince Sultan Institute for Environmental, Water, and Desert Research, King Saud University, Saudi Arabia. He earned his MS degree in International Agricultural Extension in 1992 from the Utah State University, Logan, Utah, USA, and was placed on the "Roll of Honor". He completed his Ph.D. in Extension for Natural Resource Management from the University of Idaho, USA, and was honored with the "1995 outstanding graduate student award". Dr. Baig has published extensively on the issues associated with natural resources in national and international journals. He has also presented issues in agriculture and natural resources and the role of extension education at various international conferences. Food waste, water management, degradation of environment and natural resources, and their relationship with society/community are his areas of interest. He has attempted to develop strategies to conserve natural resources, promote environment, and develop sustainable communities. Dr. Baig started his scientific career in 1983 as a researcher at the Pakistan

Agricultural Research Council, Islamabad, Pakistan. He served at the University of Guelph, Ontario, Canada, as the Special Graduate Faculty from 2000 to 2005. He served as a Foreign Professor at the Allama Iqbal Open University (AIOU), Pakistan, through Higher Education Commission from 2005 to 2009. He also served as a Professor of Agricultural Extension and Rural Society at the King Saud University, Saudi Arabia, from 2009 to 2020. He is a member of the editorial boards of many international journals and professional organizations.

Dr. Mohamed Taher Sraïri is a Senior Lecturer in Animal Science at the Hassan II Agronomy and Veterinary Medicine Institute (IAV), Rabat, Morocco. He is currently the Head of the School of Agricultural Sciences at IAV. Dr. Sraïri completed his Ph.D. in 2004 from the Gembloux Agro-Bio Tech University, Belgium. He has an experience of 26 years in research on topics related to crop-livestock systems in Morocco with a focus on dairy production. His research activities have allowed him to publish more than 60 peer-reviewed articles in international journals, as well as the participate in several conferences dedicated to livestock and agricultural sciences. He has also been associated with reviewing several manuscripts submitted to international scientific journals. He is mainly interested in crop-livestock integration, with an emphasis on resources use efficiency, particularly land, water, and work. As a consequence, he had achieved on-farm research in semi-arid to arid areas on water productivity in crop-livestock systems, in contexts where farms are in majority small-holder units, with a focus on the origin of water (whether rainfall or irrigation from surface or groundwater sources). This has necessitated an accurate characterization of the resources uses (volumes of water and hours of work) and the yields and profitability they allowed by crops and livestock products. He is currently involved in a global research network dealing with work uses in farming systems and their consequences on the attractiveness of agriculture, particularly for young generations. He is also involved in research activities with a transdisciplinary team in the oases areas, where global changes (climate, social, etc.) are severely impacting farming systems, putting at risk their resilience, in a context of severe resource scarcity.

Dr. Abdlmalek A. Alsheikh is the Director of the Prince Sultan Institute for Environmental, Water, and Desert Research at the King Saud University (KSU) in Riyadh, Saudi Arabia. He earned his Ph.D. in Arid Land Studies from the University of Arizona, USA, in 1983. He also serves as the General Secretary of the Prince Sultan bin Abdulaziz International Prize for Water (PSIPW). The Prize is awarded bi-annually at the United Nations Headquarters. Being the Director and Research Chair, he oversees the Research Programs at the Institute. He is the team leader of many research projects concerning the environment, desertification, climate change, and water harvesting in Saudi Arabia including the King Fahd Project for Water Harvesting and Storage in Saudi Arabia, Prince Sultan Project for Villages and Hamlets Rehabilitation in Saudi Arabia, and the Space Images Atlas of Saudi Arabia and the Environmental Atlas of Saudi Arabia. Being the Chairman of the international conferences on water resources and arid environments, he successfully organized them at the King Saud University. He has brought world fame water scientists to Saudi Arabia and published 9 proceedings of organized international conferences. He has published extensively in journals of international repute.

Eng. Ali Wafa A. Abu Risheh earned his M.Sc. Degree in Applied Remote Sensing from Cranfield University in the UK in 1987. He is the Head of the Department of Remote Sensing and GIS at the Prince Sultan Institute for Environmental, Water, and Desert Research at King Saud University in Riyadh. He is also the Executive Director of the Prince Sultan Bin Abdulaziz International Prize for Water and a Researcher for the Prize's dedicated research chair at KSU. He has overseen a number of projects involving remote sensing, including the Space Image Atlas of Saudi Arabia, the King Fahd Project for Water Harvesting and Storage in Saudi Arabia, and recently the Atlases of the Environmental Systems and the Sustainable Development of Saudi Arabia.

Abbreviations and Acronyms

AAV	Agricultural Added Value
ADCs	Agricultural Development Corporations
AES	Agricultural Extension Services
AESA	Agriculture Extension in South Asia
AGDP	Agricultural Gross Domestic Product
AI	Artificial Intelligence
AMEE	Moroccan Agency for Energy Efficiency
AOAD	Arab Organization for Agricultural Development
AREEO	Agricultural Research, Education and Extension Organization
ASCs	Agricultural Services Centers
ATVET	Agricultural Technical and Vocational Training
AVRDC	Asian Vegetable Research and Development Center
BDS	Basic Democracies System
CA	Conservation Agriculture
CABI	Centre for Agricultural Bioscience International
CD	Crop Diversification
CDIAC	Carbon Dioxide Information Analysis Center
CDM	Clean Development Mechanisms
CERES	Center for Environment, Human Security and Governance
CF	Collective Farms
CGIAR	Consultative Group for International Agricultural Research
CGMS	Crop Growth Monitoring System
CIAT	International Centre for Tropical Agriculture
CIMMYT	International Maize and Wheat Improvement Center
CLCA	Crop-Livestock under Conservation Agriculture
CLI	Crop-Livestock Integration
COTUGRAIN	Compagnie Grainière Tunisienne
CR	Climate Resilience
CRGE	Climate-Resilient Green Economy
CRP Livestock	CGIAR Research Program on Livestock
CSA	Climate-Smart Agriculture

CSP	Concentrating Solar Power
CV	Coefficient of Variance
CWR	Crop-Water Relationships
DEA	Data Envelopment Analysis
DOA	Department of Agriculture
DSR	Design Science Research
DZ	Dry Zone
EACCE	International Market Monitoring System
EIA	Environmental Impact Assessment
EPAS	Electronic Partner for Agro Services
FAO	Food and Agriculture Organization
FBOs	Farmer-based Organizations
FDA	Agricultural Development Fund
FFEM	French Facility for Global Environment
FFS	Farmer Field School
FGLS	Feasible Generalized Least Square
FSA	Food Security Assessment Survey
FTCs	Farmer Training Centers
GAM	General Census of Agriculture (Algeria)
GAP	Good Agriculture Practices
GCC	Golf Council Countries
GCF	Green Climate Fund
GCRI	Global Climate Risk Index
GDA	Groupements de Développement Agricole
GDP	Gross Domestic Product
GEF	Global Environment Facility
GEI	Group of Economic Interest Around Saffron
GHG	Greenhouse Gas
GMP	Green Morocco Plan
GoP	Government of Pakistan
GPS	Global Positioning System
GTP	Growth and Transformation Plan (Ethiopia)
ha	Hectare
ICARDA	International Center for Agricultural Research in the Dry Areas
ICARDA	International Centre for Agricultural Research in Dry Areas
ICIMOD	International Centre for Integrated Mountain Development
ICLS	Integrated Crop-Livestock Systems
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
ICT	Information and Communications Technology
ICT	Information Communication Technology
IEA	International Energy Agency
IEE	Initial Environmental Examination
IF	Individual Farms
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Institute

ILRI	International Livestock Research Centre
INGC	Institut National des Grandes Cultures
INRA	National Institute of Agronomic Research (Morocco)
INRAT	Institut National de Recherche Agronomique de Tunisie
INRGREF	Institut National de la Recherche en Génie Rural, Eaux et Forêts
IoTs	Internet of Things
IPC	Integrated Food Security Phase Classification
IPCC	Intergovernmental Panel on Climate Change
IRDP	Integrated Rural Development Program
IRDP	Integrated Rural Development Program' (Pakistan)
IRESA	Institution de la Recherche et de l'Enseignement Supérieur Agricoles
IRRI	International Rice Research Institute
ITGC	Institut Technique des Grandes Cultures
ITU	International Telecommunication Union
IVRs	Interactive Voice Responses
IWMI	International Water Management Institute
IZ	Intermediate Zone
KPK	Khyber Pakhtoon Khwa
KSA	Kingdom of Saudi Arabia
LDL	Low-Density Lipoprotein
MASEN	Moroccan Agency for Sustainable Energy
MEL	Monitoring, Evaluation and Learning
MEWA	Ministry of Environment, Water and Agriculture (KSA)
ML	Machine Learning
MODIS	Moderate Resolution Imaging Spectroradiometer
MTH	Mega Trading Hub
NA	North Africa
NADP	National Agricultural Development Program (Algeria)
NAES	National Agricultural Extension Service
NARS	National agricultural research system
NCCP	First National Climate Change Policy (Pakistan)
NCDs	Non-Communicable Diseases
NCP	National Water Plan (Morocco)
NDA	National Designated Authority
NFPP	National Food Production Program
NGOs	Non-Governmental Organizations
NLP	Natural Language Processing
OEP	Office de l'Elevage et des Pâturages
ONEE	Office National de l'Electricité et de l'Eau Potable
ORMVAO	Ouarzazate Regional Agricultural Development Office
PAD&SC	Punjab Agricultural Development and Supply Corporation
PARC	Pakistan Agricultural Research Council
PASDEP	Plan for Accelerated and Sustainable Development to End Poverty (Ethiopia)

PICCPMV	Project for the Integration of Climate Change in the implementation of Morocco Green Plan
PITB	Punjab Information Technology Board
PMP	Positive Mathematical Planning
PSIEWDR	Prince Sultan Institute for Environmental, Water, and Desert Research
PSIPW	Prince Sultan bin Abdulaziz International Prize for Water
Q&A	Questions and Answers
R&D	Research and Development
R4D	Research for Development
SAAB	Saudi Arabian Agricultural Bank
SABA	System of Agricultural Aid and Subsidies
SAGO	Saudi Grains Organization
SD	Standard Deviation
SDGs	Sustainable Development Goals
SDPRP	Sustainable Development and Poverty Reduction Program (Ethiopia)
SMSA	Société Mutuelle de Services Agricoles
TND	Tunisien Dinar (1 TND=0.36 US$ - average Jan-July 2021)
TRC	Telecommunication Regulatory Commission
UAA	Utilized Agricultural Area
UAL	Utilized Agricultural Land
UAVs	Unmanned Aerial Vehicles or Drones
UNDP	United Nations Development Program
UNFCCC	United Nations Framework Convention on Climate Change
UNFPA	United Nations Population Fund
UNOOSA	United Nations Office of Outer Space Affairs
UNPRI	United Nations Principles for Responsible Investing
US$	United States Dollar
USAID	United States Aid Agency
USDA	United States Department of Agriculture
USGS	United States Geological Survey
V-AID	Village Agricultural and Industrial Development Programme
VDSR	Very Deep Super-Resolution
WEF	Water-Food-Energy
WFP	World Food Program
WHO	World Health Organization
WWF	World Wildlife Fund
WZ	Wet Zone

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