Crop Wild Relatives and Climate Change

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Tribute in the Memory of Manav Yadav

Manav was born on 5 January 1981, in the family of Dr. Shyam Singh and Suvidya Yadav, Agriculture Scientist, Division of Genetics, Indian Agricultural Research Institute, New Delhi, India.

Manav Yadav went for Business Management studies to Dallas, Texas, USA, in 2005, at age 24, after completing an E-commerce degree from Indraprestha University, Delhi, India. After beginning his studies USA, he developed a unique taste in assisting with international professional publications. Thus, he motivated his father Dr. Yadav to develop a proposal for the book "Chickpea Breeding and Management." Manav played a key role as coordinator to bring out the publication of this book, which was published by CABI, UK, in 2007. Simultaneously, another book proposal on "Lentil: An Ancient Crop for Modern Times" was developed and coordinated by Manav, which was published by Springer, The Netherlands, in 2007. In the United States, he became interested in climate change and helped develop an important book proposal on "Climate Change and Management of Cool Season Grain Legume Crops." Manav managed communication with the lead authors of various chapters and coordinated the entire project from the start to the final stage of publication. Thus, the proposed book was published by Springer, The Netherlands, in 2010.

Later on, with a strong team of international editors, Manav helped to develop another book proposal on "Crop Adaptation to Climate Change." This entailed the formulation of 29 chapters on 40 field crops covering climatic changes in all the continents. Manav managed and coordinated this project at each stage of development and completion, which was published by Wiley-Blackwell Publishing, John Wiley & Sons, Inc., USA, in 2011.

The conceptual idea on the present book proposal on "Crop Wild Relatives and Climate Change" was developed with Manav Yadav in 2011. Thus, a competent team of Editors of International Professionals was identified to work on this book with the active management and coordination by Manav Yadav. The final

proposal on this book was submitted for publisher approval by Manav Yadav in the month of February 2012.

Unfortunately, we lost Manav Yadav, a talented, dynamic, innovative, committed, and devoted young leader at the age of 31 years on 17 July 2012 in Dallas, Texas, USA.

Thus, the work on this book proposal was completely halted for a year due to the untimely and sudden loss of Manav. His father, Dr. Yadav, was completely unable to take up any work for a year due to the loss of his only child Manav.

The pending work, which was difficult to complete for Dr. Yadav, was vigorously resumed by the editing team in mid-2013 and completed by March 2014. The entire team involved in the completion of this book is commemorating the memory of Manav Yadav, who was an inspiration to all of us. The international scientific community is in debt to Manav who will be remembered as an innovative, visionary, and dynamic young intellectual, a unique gift of God.

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Guest editor

Prof. Cary Fowler, Ph.D.

Before joining the Global Crop Diversity Trust as its Executive Director in 2005, Dr. Cary Fowler was Professor and Director of Research in the Department of International Environment and Development Studies at the Norwegian University of Life Sciences. Prof. Fowler retired as Executive Director of the Trust in October 2012, and currently serves as a Special Advisor to the organization.

Dr. Cary's career in the conservation of crop diversity spans four decades. In the 1990s, at the Food and Agriculture Organization (FAO) of the United Nations, he headed the team that produced the UN's first global assessment of the state of the world's plant genetic resources. He drafted and supervised negotiations of FAO's Global Plan of Action for Plant Genetic Resources, adopted by 150 countries in 1996. In same year, he served as Special Assistant to the Secretary General of the World Food Summit.

In 2004, he headed the International Committee that proposed and designed the Svalbard Global Seed Vault. Today, he chairs the Vault's International Advisory Council.

Dr. Cary is a past member of the US National Plant Genetic Resources Board and of the Board of Trustees of the International Maize and Wheat Improvement Center in Mexico and past chair of the Board of the American Livestock Breeds Conservancy. Currently, he serves on the Board of the NY Botanical Garden Corporation.

Dr. Cary has been profiled by CBS 60 Minutes and The New Yorker. He is the author of several books on the subject of crop diversity and more than 100 articles in agriculture, law, and development journals. He earned his Ph.D. at the University of Uppsala (Sweden). He has an honorary doctorate of laws from Simon Fraser University (Canada) and an honorary doctorate of science from Rhodes College (Tennessee). In 2010, he received the 2010 Heinz Award for his "vision and efforts in the preservation of the world's food supply," and the Russian Academy of Agricultural Sciences awarded him the Vavilov Medal for his "exceptional contribution" to the cause of conserving plant genetic resources for present and future generations. He was subsequently elected to the Russian Academy of Agricultural Sciences. In 2013, a documentary film centering on his life and work – "Seeds of Time" – premiered at the Copenhagen Film Festival.

Team of editors

Robert J. Redden, Ph.D.

Dr. Robert Redden completed his B.Sc. Ag. (Hons) degree at the University of Adelaide, Australia, in 1965, majoring in genetics and plant breeding, and then an M.Sc. Ag. degree in agronomy and plant breeding at the same university in 1969. He completed his Ph.D. in plant breeding and genetics at Cornell University, USA, in 1972. He was a postdoctoral

fellow in the CIMMYT wheat breeding program from 1972 to 1974 with responsibility for introgression of spring wheat traits into winter wheat. He was a wheat specialist with IITA, Nigeria, 1975–1977, to assist with the introduction of Mexican wheat into the national wheat program.

Dr. Redden transferred to the grain legume program at IITA, Ibadan, 1077–1981, with the responsibility for conducting the international cowpea breeding program. In addition, he assisted with the program for international trainees and supervised graduate students from external universities.

From 1982 to 2000, Dr. Redden was a breeder of *Phaseolus* for grains in Australia, mainly for small white "navy beans" to be processed as baked beans in tomato sauce and also for lima and for (*Vigna angularis*) adzuki beans.

From 2001 to 2013, Dr. Redden was curator of the Australian Temperate Field Crops Collection based in Horsham, Victoria, with the responsibility of temperate pulse and temperate oilseed collections across many species and minor crops. This gene bank along with two others for winter cereals and for tropical crops were amalgamated into the Australian Grains Genebank based in Horsham, where Dr Redden continues to be a curator.

In 2013, Dr. Redden was Chairman of the ICRISAT Center Commissioned External Review for its Sub-Saharan Africa research and development program. This committee reviewed the ICRISAT research settings for subtropical semiarid cereal and legume crops in both East and West Africa.

Dr. Redden has been an author for over 50 refereed articles on topics ranging from plant breeding to biometrics, genetics, plant pathology, entomology, food sciences, and genetic resources. Along with Dr. Yadav, he has been a coeditor of books on chickpea, cool season crops and climate change, and adaptation of the world's major crops to climate change, and assisted with the production of the current book *Crop Wild Relatives and Climate Change*. Dr. Redden has also contributed to chapters on lentil, pea, and faba bean genetic resources in various other books and special publications.

In 2008, Dr. Redden received the Yunnan Friendship Award for his leadership in two ACIAR legume projects in China.

Dr. Redden was a guest speaker at legume/climate change workshops with CIAT in both Tanzania and Cali, Colombia, in 2011. In 2012, he hosted the Chinese recipient of the Vavilov–Frankel scholarship for young scientists training in genetic resources.

Shyam S. Yadav, Ph.D.

Dr. Shyam S. Yadav completed his Bachelor's Degree in Agriculture at the University of Agra, Uttar Pradesh, India, in 1964, and a Master's Degree in Agriculture Botany (Genetics and Plant Breeding) from University of Meerut, Uttar Pradesh, India, in 1967. He completed his Ph.D. in Genetics and Plant Breeding at Indian Agricultural Research Institute, New Delhi, India, in 1987.

Dr. Yadav is currently working as a Freelance International Agriculture Consultant for Manav Foundation at Manav Yadav Memorial Trust, Vikaspuri, New Delhi, India. Simultaneously, he is engaged and assigned as International Research Advisor in Agriculture on Capacity Development at Agriculture Research Institute of Afghanistan, Ministry of Agriculture, Irrigation and Livestock, Government of Islamic Republic of Afghanistan, Kabul, Afghanistan.

Dr. Yadav started his professional career as Research Associate/Assistant Breeder with the main responsibility for introgression of the Mexican dwarf wheat varieties and tall Indian wheat varieties, development of new high-yielding semidwarf cultivars in the wheat breeding program at Division of Genetics, India Agricultural Research Institute (IARI), New Delhi, India, from 1969 to 1974. He then worked as an agriculture specialist with the Government of Iraq from 1974 to 1979 to assist in the development and dissemination of

crop production and management technology program. On returning back to India in 1979, Dr. Yadav joined the Chickpea Breeding Program at Indian Agricultural Research Institute, New Delhi, India, with the responsibility of developing and focusing the program on wide hybridization and introgression in chickpea to develop high-yielding, widely adapted, multiresistant and quality cultivars.

Under Dr. Yadav's leadership, the chickpea breeding team developed excellent new material of both Kabuli and Desi types. As a Program Leader of the chickpea breeding team at IARI, he was successful in developing and releasing more than 20 high-yielding, widely adapted, commercial chickpea varieties for different planting environments of India from 1988 to 2006. Some of India's pioneering and foremost chickpea varieties, namely, Pusa Kabuli 1053, 1088, 1108, 2024, and 1105 and Pusa Desi 362, 372, and 1103 were developed and released by him. Simultaneously, he also developed many unique germplasm lines that are being used in various national crop improvement programs by various chickpea breeders nationally and internationally. Dr. Yadav has also guided postgraduate students in the discipline of plant breeding on breeding approaches, methodologies, and techniques from 1990 to 2008.

Dr. Yadav served as Principal Investigator for various national and international research projects with Indian, Australian, and American research organizations during 1998–2006. In 2002, he worked as International Legumes Consultant with the Food and Agriculture Organization (FAO) of United Nations in Myanmar. In 2007, he worked as International Technical Expert on standardization of quality products of fruit and vegetable crops for international marketing with the United Nations Development Program (UNDP), Sana'a, Yemen. Later on, in the same year, he was employed as Chief Scientist by Krishidhan Seeds Pvt. Ltd., Maharashtra, India. In 2008, he was employed as Chief Scientist and, later on, as Program Leader of Rice & Grains Program at National Agricultural Research Institute, Lae, Papua New Guinea.

Thus, Dr. Yadav has vast working experience as an agriculture scientist, consultant, and expert in different countries across the continents ranging from Australia, United States, Asia, and the Pacific Region. His primary interest of research has been focused on plant breeding, development of integrated crop production and management technologies and their dissemination among farming communities at village levels in diversified ecologies, mentoring and coaching of graduate and postgraduate students, agricultural personnel, NGOs, and different stakeholders.

In his current position, Dr. Yadav is responsible for capacity development in the agricultural research sector on issues of infrastructure development, administration and management of project planning, management- and implementation-related issues, and development and dissemination of production technologies. He is also responsible for training agricultural workers on various technological aspects, including scientists, extensionists, trainers, farmers, and stakeholders under conflicting environments. He has published more than 125 research articles in various national and international journals.

He is a Fellow of the Indian Society of Genetics and Plant Breeding, Indian Society of Pulses Research and Development, and The Linnean Society of London, UK. His current book on Crop Wild Relatives and Climate Change is his fifth book as Editor. Before this, he worked as Chief Editor for books on *Crop Adaptation to Climate Change*, *Wiley-Blackwell*, *A John Wiley & Sons Ltd. Publication*, *USA*, *2011*; *Climate Change and Management of Cool Season Grain Legume Crops*, Springer, The Netherlands, 2010; *Chickpea Breeding and Management*, CABI, UK, 2007; and *Lentils*: *An Ancient Crop of Modern Times*, Springer, The Netherlands, 2007.

Nigel Maxted, Ph.D.

Nigel Maxted OND (Agric.), B.Sc. (C.N.A.A.), M.Phil. (SOTON), Ph.D. (SOTON), F.L.S., is a senior lecturer and consultant in Genetic Conservation at the School of Biosciences at the University of Birmingham, UK. Dr. Nigel's research interests are in plant conservation and broader biodiversity conservation and use, with specific expertise in: field conservation, taxonomy, ecogeography, GIS, reserve management, on-farm conservation, gene flow, and genetic diversity studies of various plant groups. He has work experience on conservation throughout Africa, the Middle East, Caucasus, Central Asia, and Europe.

Positions held by Dr, *Nigel*: (1) January 2014 to date: Project partner in an EU ACP Programme project entitled Developing CWR conservation strategies for Southern Africa. (2) January 2012 to date: Project partner in an EU ERA funded project entitled Reinforcing Cooperation between the Royal Botanic Garden of Jordan and European Research Area. (3) March 2011 to date: Project partner in a Norwegian Government grant of US$ 50M for Adapting Agriculture to Climate Change: Collecting, Protecting, and Preparing Crop Wild Relatives. (4) March 2011 to date: Principle investigator for an EC FP7 Research Novel characterization of crop wild relatives and landraces resources as a basis for improved crop breeding (PGR Secure). (5) June 2009 to date: Principle investigator for an IUCN funded project concerned with IUCN red listing of European crop wild relative diversity. (6) February 2003 to date: Cochair of the IUCN Species Survival Commission Crop Wild Relative Specialist Group. (7) January 2003 to date: Principle investigator for a DEFRA funded project concerned with the inventory and conservation of UK's agrobiodiversity and (8) December 1985 to date: Conservation gap and ecogeographic analysis linked to the targeted conservation activities.

Dr. Nigel management Competence was as *coordinator/director* of national and international research projects addressing *in situ* and *ex situ* conservation of plant genetic resources in Europe, Asia, and Africa, for various international agencies (FAO/IPGRI/World Bank/the United Nations). He successfully coordinated three large EC funded projects and regularly works as a consultant for leading international conservation agencies.

Dr. Nigel worked on various programs: *as a Senior Scientific Advisor* for the GEF/World Bank (Plant Genetic Resources Conservation) in Turkey and the Middle East; *Chair* of the European Cooperative Programme/Genetic Resources *In Situ* and On-Farm Network; *Chair* of Wild Species Conservation in Genetic Reserves WG; *Cochair* of the IUCN SSC Crop Wild Relative Specialist Group; Chair of the UK Plant Genetic Resources Group; *Associate Advisor* for the British Council in Biodiversity Conservation, and *Visiting Research Fellow* at the Royal Botanic Gardens, Kew.

*Dr. Nigel has worked on different capacity building programs and has an excellent training experience on e*xtensive teaching at undergraduate and postgraduate levels, as well as vocational and field course training experience in biodiversity conservation, taxonomy, and plant genetic resources management. He has supervised 30 Ph.D., 7 M.Phil., 14 MRes, and more than 100 M.Sc. research projects. *Dr. Nigel has published over* 100 peer-reviewed research papers, and in the past 10 years, he wrote or edited 18 books on various aspects of biodiversity conservation and use.

Ehsan Dulloo, Ph.D.

Dr. Ehsan Dulloo completed his B.Sc. (Hons) degree in Environmental Biology with Comparative Physiology (1980), Queen Mary College, University of London, and M.Sc. degree in Conservation and Use of Plant Genetic Resources (1990), University of Birmingham, UK. He completed his Ph.D. degree in Conservation biology from the University of Birmingham, UK, in 1998.

Dr. Dulloo, born in 1957 (Mauritius), first joined Bioversity International in 1999. He left Bioversity in 2011 to join FAO as Senior Officer and subsequently rejoined Bioversity in November 2012 as Leader of the Conservation and Availability Programme. In his capacity, he provides scientific leadership for *in situ* conservation of crop wild relatives and on-farm conservation and oversight on the policy and informatics work of Bioversity. Among his major achievements, Dr. Dulloo conceptualized the World Bank 2009 award-winning proposal "Seeds for Needs" in Ethiopia, on the use of gene bank material in adapting to climate change, which was also implemented in Papua New Guinea. He contributed to the development of the successful UNEP/GEF project on *in situ* conservation of crop wild relatives and established the CGIAR Crop Genebank Knowledge Base. He has been a lead author for the preparation of FAO's First and Second State of the World Reports on plant genetic resources and the 2005 Millennium Ecosystem Assessment report. Before joining Bioversity, Dr. Dulloo led two GEF projects to restore degraded islands around Mauritius and developed Mauritius' first National Park. Dr. Dulloo is a member of the Plant Sub-Committee of IUCN/SSC and cochair of the Crop Wild Relative Specialist Group.

Luigi Guarino, Ph. D.

Luigi Guarino, an Italian national, is currently Senior Scientist at the Global Crop Diversity Trust in Bonn, Germany. He served as a consultant for the Food and Agriculture Organization of the United Nations and the International Bureau of Plant Genetic Resources (IBPGR) from 1984 to 1987. He then worked full-time for IBPGR from 1987 to 1992, on a number of germplasm collection, characterization, and documentation projects, mainly in support of national programs in North Africa, the Middle East, and the South Pacific. He was subsequently appointed to work on genetic diversity issues in the Sub-Saharan Africa regional office of Bioversity International (formerly IPGRI) based in Nairobi, Kenya. He transferred to the Bioversity regional office for the Americas in Cali, Colombia, in 1997. From there, he coordinated a global research agenda on measuring, locating, and monitoring genetic diversity, with particular responsibility for the application of geographic information systems (GIS), and also managed work on germplasm use in the region, including research on patterns of use of *ex situ* collections. He had responsibility for national and regional program development in the Caribbean subregion. He moved on to the position of Plant Genetic Resources Adviser at the Secretariat of the Pacific Community (SPC), based in Fiji, in 2003. At SPC, he coordinated and managed the Pacific Plant Genetic Resources Network (PAPGREN). He also assisted with the development of genetic resources policy at the national and regional levels. In his current position at the Trust, he is involved in the technical implementation of a global program aimed at ensuring the long-term conservation *ex situ* and sustainable use of crop genetic resources. Luigi has published numerous scientific research papers in different international journals of repute. He has written many book chapters for various books published internationally and has been a part of a number of editing teams. He is an active blogger on agrobiodiversity issues (http://agro.biodiver.se) and has an interest in the use of social networking in conservation.

Paul P. Smith, Ph.D.

Paul Smith is a specialist in plant diversity in southern, central, and eastern Africa. He has vast experience in seed conservation, ecological survey, botanical inventory, vegetation mapping, and environmental monitoring. He has published numerous papers in this field and is the author of two field guides to the plants of south-central Africa. He edited the *Ecological Survey of Zambia* (2001) and the *Vegetation Atlas of Madagascar* (2007), both published by Kew.

In August 2005, Dr. Smith was appointed Head of Kew's Seed Conservation Department and leader of the Millennium Seed Bank Partnership, a network of more than 170 plant science institutions in 80 countries. In October 2009, the Partnership achieved its first milestone of storing seeds from 10% of the world's plant species both in the MSB and in the countries of origin. Over the next 10 years, the Partnership will seek to secure 25% of the world's flora in seed banks and to enable the use of those seeds for human innovation in agriculture, horticulture, forestry, and habitat restoration.

Kew's Millennium Seed Bank comanages the "Adapting Agriculture to Climate Change" project with the Global Crop Diversity Trust. This 10-year program aims to collect, store, and characterize seeds from the wild relatives of 29 of the world's major crops. Seed material will be stored, for a long term, against the risk of extinction and made available to plant breeders worldwide.

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Foreword by Prof. Geoffrey Hawtin

The forthcoming book entitled "Crop Wild Relatives and Climate Change" addresses a topic that is critically important to future food security. With food demand growing rapidly and rising temperatures decreasing global food production potential, agricultural scientists must work ever harder to stay ahead of the climate change curve. Plant breeding offers a key route to address this challenge through the development of new varieties that are able to withstand the predicted adverse effects of climate change or that can capitalize on its more positive aspects such as CO_2 fertilization or higher average temperatures in some temperate zones.

It is well recognized that the wild relatives of our crops could provide a wealth of useful traits for the development of such improved varieties. However, while the potential may be enormous, they remain a greatly underused resource.

This book brings together an impressive array of leading world scientists in this area, under the overall guest editorship of Prof. Cary Fowler. The conservation and use of crop wild relatives are explored from many different angles, and the book will undoubtedly serve as an important information source for many years to come.

Geoffrey Hawtin
Senior Technical Advisor, International Treaty on Plant Genetic Resources for Food and Agriculture, Italy
Advisor, Global Crop Diversity Trust, Germany
Member, Board of Trustees, Royal Botanical Gardens, Kew, UK
Vice Chair, Board of Trustees, Centro Internacional de Agricultura Tropical, (CIAT) Colombia

Foreword by Dr. R S Paroda

Crop wild relatives (CWR) are the species closely related to field crops, including their progenitors, and have the potential to contribute beneficial traits for crop improvement such as resistance to biotic and abiotic stresses and to enrich the gene pool, leading to improved yield and stability. CWR are recognized as a critical resource to sustain global food security, and therefore, their systematic collection, characterization, conservation, and use in crop breeding are imperative.

The changing climate is a major threat to agrobiodiversity, ecosystems, and human survival globally. The International Panel on Climate Change, in their 2014 report, predicted that global climate will change radically during the 21st century, which might result in both positive and negative impacts on field crops. Thus, a major task before us is to ensure sustainable food and nutrition security of the world's current population (now nearing 7.5 billion). The current projections suggest that the world's temperatures will rise by 1.8–4.0°C and the population may reach more than 10 billion by 2100, after which it may stabilize.

The natural "greenhouse effect" makes the temperature regime of some regions more hospitable to life forms especially at high altitudes and high latitudes. However, the progressive rise in the concentration of some atmospheric gases due to human activity poses the danger of excessive global warming. The primary culprit gases emitted are CO_2, CH_4, and N_2O. The accumulation of CO_2 has changed from the preindustrial value of 20 parts per million (ppm) to a level approaching 400 ppm – a 40% rise. Unless the emissions of greenhouse gases are curbed significantly, their concentration will continue to rise, leading to irreversible changes in temperature, precipitation, and other climate variables with severe consequences for agriculture around the world.

Humans achieved a revolutionary breakthrough with the first domestication of crops around 11,000 years ago using astute but empirical phenotypic selection. Can we now raise agriculture to a new level, linking the genetic code to phenotypic expressions and the management of responses to new environments? By selecting novel genes from crop wild relatives and using these in developing improved crop varieties, agriculture may be able to combat the threatening challenges of climate change.

This book contains 20 chapters covering various aspects of crop wild relatives including impact of climate change on agriculture, challenges for future agriculture, crop evolution, crop adaptation, importance of crop wild relatives, locating and conserving, research on crop wild relatives in major food and vegetable crops as well as minor fruit crops, hybridization, biotechnology, and genomics, *in situ* and *ex situ* conservation including Svalbard conservation, economic value of crop wild relatives and crop wild relatives beyond biodiversity for ecosystem services. The book well integrates all these important aspects and will prove useful in developing strategies to cope with the vagaries

of climate change and to meet the production challenges of food for unprecedented population increases.

The significant contribution of well-qualified internationally known professionals in the Editorial Team and also the lead and coauthors of different chapters is highly appreciable, and I congratulate them for their commendable job. The involvement of internationally well-known publishing house Wiley-Blackwell, Inc., USA, also adds value to the quality of publication

I am sure that the book entitled "Crop Wild Relatives and Climate Change" will be immensely useful to researchers, academicians, policy planners, and students.

Raj Paroda
Chairman, TAAS and Haryana Farmers Commission
Executive Secretary, APAARI
Formerly, Secretary DARE, Govt. of India, Director General, ICAR

Preface

The growing concern over the potentially devastating impacts of climate change on biodiversity and food security, considered along with the growing world population, means that taking action to conserve crop wild relative (CWR) diversity is no longer an option but an urgent priority. CWRs are a key tool for addressing the limits of genetic variation in domestic crops for adapting to climate change. The wild progenitors of crops and their close relatives have the potential to contribute beneficial traits for crop improvement, such as biotic and abiotic resistances especially for tolerance of extreme high temperature and drought stresses, leading to improved yield and stability under climate change. Having already made major contributions to crop improvement in the 20th century, CWRs are recognized as a critical resource to sustain global food security; therefore, their systematic conservation is imperative. However, extension of their conservation and promotion of more systematic exploitation are hindered by the lack of understanding of their current and potential value, their diversity, and practically how they might be conserved.

Climate change is a reality in today's world and, along with the unprecedented increase in the world's population, underlines a looming food security issue. At least 70% more food production will be required by 2050 in a more challenging climate. More severe spikes in heat stress are expected during the reproductive phase of crops as compared to that previously experienced in crop evolution, and targeted exploitation of novel sources of genetic diversity will be a necessity. The Stern Review on the Economics of Climate Change in 2006 and the Fourth Assessment Report by the Intergovernmental Panel on Climate Change in 2007 have pushed the scientific and public debates on climate change a decisive step forward. Substantial further changes in climate are likely to occur even with aggressive mitigation efforts.

The human population is projected to increase from the current 7 billion to 10.5 billion within a period of only 70 to 80 years. Meeting the needs of these additional people will require substantial increases in production of agricultural systems using essentially the same area of arable land as is used today, or less due to expansion of cities. Current agricultural systems are to a certain extent adapted to the current climates. Substantial changes in agricultural systems will be needed in the many regions subjected to critical changes in climate, especially if these systems are to have greater productivity. Many of the world's poor live in arid and semiarid zones under environmental conditions that currently are challenging. In addition, these farmers do not have the resources to facilitate adaptation of their cropping systems to changing climates. Most developing countries are highly dependent on agricultural sectors likely to be affected by climate change and have institutions with limited capacity to develop improved cropping systems. Consequently, a collaborative effort by the world's agricultural scientists is needed if the necessary changes to

agricultural systems are to be made to achieve sustainable food security.

This book contributes to this collaborative effort by providing reviews by a group of international scientists with expertise in the principal crops grown in tropical and temperate zones. Projections are provided of the extent to which climate change will influence the potential of CWRs and productivity of field crops in different regions of the world. Opportunities for developing improved crop varieties with the intensive utilization of CWR, their conservation, collection, seed biology, economic uses, biotechnological applications, and cropping systems adapted to future climates through plant breeding approaches and changes in crop management are described. The goals of this book are: (i) to provide professional intensive knowledge and skill on the potential for CWR utilization and conservation under changing and warming climates, (ii) to provide a blueprint to breed more resilient crops that can adapt to future climate change and also be more productive in sustainable cropping systems, and (iii) to encourage the political, institutional, and financial support needed for the utilization of CWR in doubling the agricultural production during this century.

The publication of this book will provide an excellent opportunity on various issues of CWR and climate change to the international agricultural community, including scientists, technocrats, students, planners, policy makers, and lead farmers at a global level.

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