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978-1-107-05807-1 - Climate Change 2014: Impacts, Adaptation, and Vulnerability: Part A: Global and Sectoral Aspects: Working Group II Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change

Edited by Christopher B. Field and Vicente R. Barros

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# Climate Change 2014

## Impacts, Adaptation, and Vulnerability

### Part A: Global and Sectoral Aspects

Working Group II Contribution to the  
Fifth Assessment Report of the  
Intergovernmental Panel on Climate Change

Edited by

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Planting of mangrove seedlings in Funafala, Funafuti Atoll, Tuvalu. © David J. Wilson

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## Foreword

*Climate Change 2014: Impacts, Adaptation, and Vulnerability* is the second volume of the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) — *Climate Change 2013/2014* — and was prepared by its Working Group II. The volume focuses on why climate change matters and is organized into two parts, devoted respectively to human and natural systems and regional aspects, incorporating results from the reports of Working Groups I and III. The volume addresses impacts that have already occurred and risks of future impacts, especially the way those risks change with the amount of climate change that occurs and with investments in adaptation to climate changes that cannot be avoided. For both past and future impacts, a core focus of the assessment is characterizing knowledge about vulnerability, the characteristics and interactions that make some events devastating, while others pass with little notice.

Three elements are new in this assessment. Each contributes to a richer, more nuanced understanding of climate change in its real-world context. The first new element is a major expansion of the topics covered in the assessment. In moving from 20 chapters in the AR4 to 30 in the AR5, the Working Group II assessment makes it clear that expanding knowledge about climate change and its impacts mandates attention to more sectors, including sectors related to human security, livelihoods, and the oceans. The second new element is a pervasive focus on risk, where risk captures the combination of uncertain outcomes and something of value at stake. A framing based on risk provides a framework for utilizing information on the full range of possible outcomes, including not only most likely outcomes but also low probability but high consequence events. The third new element is solid grounding in the evidence that impacts of climate change typically involve a number of interacting factors, with climate change adding new dimensions and complications. The implication is that understanding the impacts of climate change requires a very broad perspective.



**M. Jarraud**  
Secretary-General  
World Meteorological Organization

The IPCC was established by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) in 1988, with the mandate to provide the world community with the most up-to-date and comprehensive scientific, technical, and socio-economic information about climate change. The IPCC assessments have since then played a major role in motivating governments to adopt and implement policies in responding to climate change, including the United Nations Framework Convention on Climate Change and the Kyoto Protocol. IPCC's AR5 provides an important foundation of information for the world's policymakers, to help them respond to the challenge of climate change.

The *Impacts, Adaptation, and Vulnerability* report was made possible thanks to the commitment and voluntary labor of a large number of leading scientists. We would like to express our gratitude to all Coordinating Lead Authors, Lead Authors, Contributing Authors, Review Editors, and Reviewers. We would also like to thank the staff of the Working Group II Technical Support Unit and the IPCC Secretariat for their dedication in organizing the production of a very successful IPCC report. Furthermore, we would like to express our thanks to Dr. Rajendra K. Pachauri, Chairman of the IPCC, for his patient and constant guidance through the process, and to Drs. Vicente Barros and Chris Field, Co-Chairs of Working Group II, for their skillful leadership. We also wish to acknowledge and thank those governments and institutions that contributed to the IPCC Trust Fund and supported the participation of their resident scientists in the IPCC process. We would like to mention in particular the Government of the United States of America, which funded the Technical Support Unit; the Government of Japan, which hosted the plenary session for the approval of the report; and the Governments of Japan, United States of America, Argentina, and Slovenia, which hosted the drafting sessions to prepare the report.



**A. Steiner**  
Executive Director  
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## Preface

The Working Group II contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC WGII AR5) considers climate change impacts, adaptation, and vulnerability. It provides a comprehensive, up-to-date picture of the current state of knowledge and level of certainty, based on the available scientific, technical, and socio-economic literature. As with all IPCC products, the report is the result of an assessment process designed to highlight both big-picture messages and key details, to integrate knowledge from diverse disciplines, to evaluate the strength of evidence underlying findings, and to identify topics where understanding is incomplete. The focus of the assessment is providing information to support good decisions by stakeholders at all levels. The assessment is a unique source of background for decision support, while scrupulously avoiding advocacy for particular policy options.

### Scope of the Report

Climate change impacts, adaptation, and vulnerability span a vast range of topics. With the deepening of knowledge about climate change, we see connections in expanding and diverse areas, activities, and assets at risk. Early research focused on direct impacts of temperature and rainfall on humans, crops, and wild plants and animals. New evidence points to the importance of understanding not only these direct impacts but also potential indirect impacts, including impacts that can be transmitted around the world through trade, travel, and security. As a consequence, few aspects of the human endeavor or of natural ecosystem processes are isolated from possible impacts in a changing climate. The interconnectedness of the Earth system makes it impossible to draw a confined boundary around climate change impacts, adaptation, and vulnerability. This report does not attempt to bound the issue. Instead, it focuses on core elements and identifies connecting points where the issue of climate change overlaps with or merges into other issues.

The integrative nature of the climate change issue underlies three major new elements of the WGII contribution to the AR5. The first is explicit coverage of a larger range of topics, with new chapters. Increasing knowledge, expressed in a rapidly growing corpus of published literature, enables deeper assessment in a number of areas. Some of these are geographic, especially the addition of two chapters on oceans. Other new chapters further develop topics covered in earlier assessments, reflecting the increased sophistication of the available research. Expanded coverage of human settlements, security, and livelihoods builds on new research concerning human dimensions of climate change. A large increase in the published literature on adaptation motivates assessment in a suite of chapters.

A second new emphasis is the focus on climate change as a challenge in managing and reducing risk, as well as capitalizing on opportunities. There are several advantages to understanding the risk of impacts from climate change as resulting from the overlap of hazards from the physical climate and the vulnerability and exposure of people, ecosystems, and assets. Some of the advantages accrue from the opportunity to evaluate factors that regulate each component of risk. Others relate to the way

that a focus on risk can clarify bridges to solutions. A focus on risk can link historical experience with future projections. It helps integrate the role of extremes. And it highlights the importance of considering the full range of possible outcomes, while opening the door to a range of tools relevant to decision making under uncertainty.

A third new emphasis ties together the interconnectedness of climate change with a focus on risk. Risks of climate change unfold in environments with many interacting processes and stressors. Often, climate change acts mainly through adding new dimensions and complications to sometimes longstanding challenges. Appreciating the multi-stressor context of the risks of climate change can open doors to new insights and approaches for solutions.

Increased knowledge of the risks of climate change can be a starting point for understanding the opportunities for and implications of possible solutions. Some of the solution space is in the domain of mitigation, extensively covered by the Working Group III contribution to the AR5. The WGII AR5 delves deep into adaptation. But many opportunities exist in linking climate change adaptation, mitigation, and sustainable development. In contrast to past literature that tended to characterize adaptation, mitigation, and sustainable development as competing agendas, new literature identifies complementarities. It shines light on options for leveraging investments in managing and reducing the risks of climate change to enable vibrant communities, robust economies, and healthy ecosystems, in all parts of the world.

### Structure of the Report

The Working Group II contribution to the IPCC Fifth Assessment Report consists of a brief summary for policymakers, a longer technical summary, and 30 thematic chapters, plus supporting annexes. A series of cross-chapter boxes and a collection of Frequently Asked Questions provide an integrated perspective on selected key issues. Electronic versions of all the printed contents, plus supplemental online material, are available at no charge at [www.ipcc.ch](http://www.ipcc.ch).

The report is published in two parts. Part A covers global-scale topics for a wide range of sectors, covering physical, biological, and human systems. Part B considers the same topics, but from a regional perspective, exploring the issues that arise from the juxtaposition of climate change, environment, and available resources. Conceptually, there is some overlap between the material in Parts A and B, but the contrast in framing makes each part uniquely relevant to a particular group of stakeholders. For setting context and meeting the needs of users focused on regional-scale issues, Part B extracts selected materials from the Working Group I and Working Group III contributions to the Fifth Assessment Report. To acknowledge the different purposes for the two parts and the balanced contributions of the co-chairs, the listing order of the editors differs between the two parts, with Chris Field listed first on Part A and Vicente Barros listed first on Part B.

The 20 chapters in Part A are arranged in six thematic groups.

## Preface

### Context for the AR5

The two chapters in this group, (1) Point of departure and (2) Foundations for decision making, briefly summarize the conclusions of the Fourth Assessment Report and the Working Group I contribution to the AR5. They explain the motivation for the focus on climate change as a challenge in managing and reducing risks and assess the relevance of diverse approaches to decision making in the context of climate change.

### Natural and Managed Resources and Systems, and Their Uses

The five chapters in this group, (3) Freshwater resources, (4) Terrestrial and inland water systems, (5) Coastal systems and low-lying areas, (6) Ocean systems, and (7) Food security and food production systems, cover diverse sectors, with a new emphasis on resource security. The ocean systems chapter, focused on the processes at work in ocean ecosystems, is a major element of the increased coverage of oceans in the WGII AR5.

### Human Settlements, Industry, and Infrastructure

The three chapters in this group, (8) Urban areas, (9) Rural areas, and (10) Key economic sectors and services, provide expanded coverage of settlements and economic activity. With so many people living in and moving to cities, urban areas are increasingly important in understanding the climate change issue.

### Human Health, Well-Being, and Security

The three chapters in this group, (11) Human health: impacts, adaptation, and co-benefits, (12) Human security, and (13) Livelihoods and poverty, increase the focus on people. These chapters address a wide range of processes, from vector-borne disease through conflict and migration. They assess the relevance of local and traditional knowledge.

### Adaptation

An expanded treatment of adaptation is one of the signature changes in the WGII AR5. Chapters treat (14) Adaptation needs and options, (15) Adaptation planning and implementation, (16) Adaptation opportunities, constraints, and limits, and (17) Economics of adaptation. This coverage reflects a large increase in literature and the emergence of climate-change adaptation plans in many countries and concrete action in some.

### Multi-Sector Impacts, Risks, Vulnerabilities, and Opportunities

The three chapters in this group, (18) Detection and attribution of observed impacts, (19) Emergent risks and key vulnerabilities, and (20)

Climate-resilient pathways: adaptation, mitigation, and sustainable development, collect material from the chapters in both Parts A and B to provide a sharp focus on aspects of climate change that emerge only by examining many examples across the regions of the Earth and the entirety of the human endeavor. These chapters provide an integrative view of three central questions related to understanding risks in a changing climate – what are the impacts to date (and how certain is the link to climate change), what are the most important risks looking forward, and what are the opportunities for linking responses to climate change with other societal goals.

The 10 chapters in Part B start with a chapter, (21) Regional context, structured to help readers understand and capitalize on regional information. It is followed by chapters on 9 world regions: (22) Africa, (23) Europe, (24) Asia, (25) Australasia, (26) North America, (27) Central and South America, (28) Polar regions, (29) Small islands, and (30) The ocean (taking a regional cut through ocean issues, including human utilization of ocean resources). Each chapter in this part is an all-in-one resource for regional stakeholders, while also contributing to and building from the global assessment. Regional climate-change maps, which complement the Working Group I Atlas of Global and Regional Climate Projections, and quantified key regional risks are highlights of these chapters. Each chapter explores the issues and themes that are most relevant in the region.

## Process

The Working Group II contribution to the IPCC Fifth Assessment Report was prepared in accordance with the procedures of the IPCC. Chapter outlines were discussed and defined at a scoping meeting in Venice in July 2009, and outlines for the three Working Group contributions were approved at the 31st session of the Panel in November 2009, in Bali, Indonesia. Governments and IPCC observer organizations nominated experts for the author team. The team of 64 Coordinating Lead Authors, 179 Lead Authors, and 66 Review Editors was selected by the WGII Bureau and accepted by the IPCC Bureau in May 2010. More than 400 Contributing Authors, selected by the chapter author teams, contributed text.

Drafts prepared by the author teams were submitted for two rounds of formal review by experts, of which one was also a review by governments. Author teams revised the draft chapters after each round of review, with Review Editors working to assure that every review comment was fully considered, and where appropriate, chapters were adjusted to reflect points raised in the reviews. In addition, governments participated in a final round of review of the draft Summary for Policymakers. All of the chapter drafts, review comments, and author responses are available online via [www.ipcc.ch](http://www.ipcc.ch). Across all of the drafts, the WGII contribution to the AR5 received 50,492 comments from 1,729 individual expert reviewers from 84 countries. The Summary for Policymakers was approved line-by-line by the Panel, and the underlying chapters were accepted at the 10th Session of IPCC Working Group II and the 38th Session of the IPCC Panel, meeting in Yokohama, Japan, from March 25-30, 2014.

## Acknowledgments

For the AR5, Working Group II had an amazing author team. In many ways, the author team encompasses the entire scientific community, including scientists who conducted the research and wrote the research papers on which the assessment is based, and the reviewers who contributed their wisdom in more than 50,000 review comments. But the process really ran on the sophistication, wisdom, and dedication of the 309 individuals from 70 countries who comprise the WGII team of Coordinating Lead Authors, Lead Authors, and Review Editors. These individuals, with the support of a talented group of volunteer chapter scientists and the assistance of scores of contributing authors, demonstrated an inspirational commitment to scientific quality and public service. Tragically, three of our most experienced authors passed away while the report was being written. We greatly miss JoAnn Carmin, Abby Sallenger, and Steve Schneider.

We benefitted greatly from the advice and guidance of the Working Group II Bureau: Amjad Abdulla (Maldives), Eduardo Calvo Buendía (Peru), José M. Moreno (Spain), Nirivololona Raholijao (Madagascar), Sergey Semenov (Russian Federation), and Neville Smith (Australia). Their understanding of regional resources and concerns has been invaluable.

Throughout the AR5, we benefitted greatly from the wisdom and insight of our colleagues in the IPCC leadership, especially the IPCC chair, R.K. Pachauri. All of the members of the IPCC Executive Committee worked effectively and selflessly on issues related to the reports from all three working groups. We extend a heartfelt thanks to all of the members of the ExCom: R.K. Pachauri, Ottmar Edenhofer, Ismail El Gizouli, Taka Hiraishi, Thelma Krug, Hoesung Lee, Ramón Pichs Madruga, Qin Dahe, Youba Sokona, Thomas Stocker, and Jean-Pascal van Ypersele.

We are very appreciative of the enthusiastic cooperation of the nations that hosted our excellent working meetings, including four lead author meetings and the 10th Session of Working Group II. We gratefully acknowledge the support of the governments of Japan, the United States, Argentina, and Slovenia for hosting the lead author meetings, and the

government of Japan for hosting the approval session. The government of the United States provided essential financial support for the Working Group II Technical Support Unit. Special thanks to the principals of the United States Global Change Research Program for orchestrating the funding across many research agencies.

We want very much to thank the staff of the IPCC Secretariat: Renate Christ, Gaetano Leone, Carlos Martin-Novella, Jonathan Lynn, Brenda Abrar-Milani, Jesbin Baidya, Laura Biagioni, Mary Jean Burer, Annie Courtin, Judith Ewa, Joelle Fernandez, Nina Peeva, Sophie Schlingemann, Amy Smith, and Werani Zabula. Thanks to Francis Hayes who served as conference officer for the approval session. Thanks to the individuals who coordinated the organization for each of the lead authors meetings. This was Mizue Yuzurihara and Claire Summers for LAM1, Sandy MacCracken for LAM2, Ramiro Saurral for LAM3, and Mojca Deželak for LAM4. Students from Japan, the United States, Argentina, and Slovenia helped with the lead author meetings.

The WGII Technical Support Unit was fabulous. They combined scientific sophistication, technical excellence, artistic vision, deep resilience, and profound dedication, not to mention a marked ability to compensate for oversights by and deficiencies of the co-chairs. Dave Dokken, Mike Mastrandrea, Katie Mach, Kris Ebi, Monalisa Chatterjee, Sandy MacCracken, Eric Kissel, Yuka Estrada, Leslie White, Eren Bilir, Rob Genova, Beti Girma, Andrew Levy, and Patricia Mastrandrea have all made wonderful contributions to the report. In addition, the work of David Ropeik (frequently asked questions), Marcos Senet (assistant to Vicente Barros), Terry Kornak (technical edits), Marilyn Anderson (index), Liu Yingjie (Chinese author support), and Janak Pathak (UNEP communications) made a big difference. Kyle Terran, Gete Bond, and Sandi Fikes facilitated travel. Volunteer contributions from John Kelley and Ambarish Malpani greatly enhanced reference management. Catherine Lemmi, Ian Sparkman, and Danielle Olivera were super interns.

We extend a deep, personal thanks to our families and to the families of every author and reviewer. We know you tolerated many late nights and weekends with partners, parents, or children sitting at the computer or mumbling about one more assignment from us.



Vicente Barros  
IPCC WGII Co-Chair



Chris Field  
IPCC WGII Co-Chair

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## Dedication



Credit: Odd-Steinar Tøllefsen

**Yuri Antonievich Izrael**  
(15 May 1930 to 23 January 2014)

The Working Group II contribution to the IPCC Fifth Assessment Report is dedicated to the memory of Professor Yuri Antonievich Izrael, first Chair of Working Group II from 1988 to 1992 and IPCC Vice Chair from 1992 to 2008. Professor Izrael was a pioneer, opening doors that have allowed thousands of scientists to contribute to the work of the IPCC.

Through a long and distinguished career, Professor Izrael was a strong proponent of environmental sciences, meteorology, climatology, and international organizations, especially the IPCC and the World Meteorological Organization. A creative researcher and tireless institution builder, Dr. Izrael founded and for more than two decades led the Institute of Global Climate and Ecology.

In the IPCC, Professor Izrael played a central role in creating the balance of IPCC efforts on careful observations, mechanisms, and systematic projections using scenarios. An outspoken advocate for the robust integration of scientific excellence and broad participation in IPCC reports, Dr. Izrael pioneered many of the features that assure the comprehensiveness and integrity of IPCC reports.

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