

Climate Change 2022: Impacts, Adaptation and Vulnerability

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

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Foreword, Preface and Dedication

Foreword

'*Climate Change 2022: Impacts, Adaptation and Vulnerability*', the Working Group II contribution to the Intergovernmental Panel on Climate Change's (IPCC) Sixth Assessment Report presents a comprehensive assessment of the current state of knowledge of the observed impacts and projected risks of climate change as well as the adaptation options. The report confirms the strong interactions of the natural, social and climate systems and that human-induced climate change has caused widespread adverse impacts to nature and people. It is clear that across sectors and regions, the most vulnerable people and systems are disproportionately affected and climate extremes have led to irreversible impacts. The assessment underscores the importance of limiting global warming to 1.5°C if we are to achieve a fair, equitable and sustainable world. While the assessment concluded that there are feasible and effective adaptation options which can reduce risks to nature and people, it also found that there are limits to adaptation and that there is a need for increased ambition in both adaptation and mitigation. These and other findings confirm and enhance our understanding of the importance of climate resilient development across sectors and regions and, as such, demands the urgent attention of both policymakers and the general public.

As an intergovernmental body jointly established in 1988 by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP), the IPCC has provided policymakers with the most authoritative and objective scientific and technical assessments. Beginning in 1990, this series of IPCC Assessment Reports, Special Reports, Technical Papers, Methodology Reports and other products have become standard works of reference.

This Working Group II contribution to the IPCC's Sixth Assessment Report contains important new scientific, technical and socio-economic knowledge that can be used to produce information and services for assisting society to act to address the challenges of climate change. The timing is particularly significant, as this information provides a new impetus, through clear assessment findings, to inform the first Global Stocktake under the United Nations Framework Convention on Climate Change.

This Working Group II assessment was made possible thanks to the commitment and dedication of many hundreds of experts worldwide,



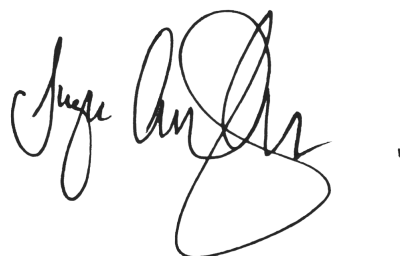
Petteri Taalas
Secretary-General
World Meteorological Organization

representing a wide range of disciplines. WMO and UNEP are proud that so many of the experts belong to their communities and networks. We express our deep gratitude to all authors, review editors and expert reviewers for devoting their knowledge, expertise and time especially given the challenges created by the Covid pandemic. We would like to thank the staff of the Working Group II Technical Support Unit, the WGII Science Advisor and the IPCC Secretariat for their dedication.

We are also grateful to the governments that supported their scientists' participation in developing this report and that contributed to the IPCC Trust Fund to provide for the essential participation of experts from developing countries and countries with economies in transition. We would like to express our appreciation to the government of Ethiopia for hosting the scoping meeting for the IPCC's Sixth Assessment Report, to the governments of South Africa, Nepal, Portugal and Guatemala for hosting drafting meetings of the Working Group II contribution and to the government of Germany for hosting the Twelfth Session of Working Group II held virtually for approval of the Working Group II Report. The generous financial support by the government of Germany and the logistical support by the Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research (Germany), enabled the smooth operation of the Working Group II Technical Support Unit in Bremen, Germany. Additional funding from the Governments of Germany, Norway and New Zealand provided key support to the Technical Support Unit office in Durban, South Africa.

We would particularly like to thank Dr Hoesung Lee, Chairman of the IPCC, for his direction of the IPCC and we express our deep gratitude to Dr Hans-Otto Pörtner and Dr Debra Roberts, the Co-Chairs of Working Group II for their tireless leadership throughout the development and production of this report.

Climate change is a long-term challenge, but the need for urgent action now is clear. The conclusion of the report's Summary for Policymakers summarizes this succinctly. 'The cumulative scientific evidence is unequivocal: climate change is a threat to human well-being and planetary health. Any further delay in concerted anticipatory global action on adaptation and mitigation will miss a brief and rapidly closing window of opportunity to secure a livable and sustainable future for all.' We couldn't agree more.



Inger Andersen
Executive Director
United Nations Environment Programme

Preface

The Working Group II contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) provides a comprehensive assessment of the scientific, technical and socio-economic literature relevant to impacts, adaptation and vulnerability. It builds upon the Working Group II contribution to the IPCC's Fifth Assessment Report, the three Special Reports of the Sixth Assessment cycle: 'Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty (SR1.5)'; 'Climate Change and Land: An IPCC Special Report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems (SRCCL)'; 'IPCC Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC)', and the Working Group I contribution to the IPCC Sixth Assessment Report.

The report recognizes the interactions of climate, ecosystems and biodiversity, and human societies, and integrates knowledge more strongly across the natural, ecological, social and economic sciences than earlier IPCC assessments. The assessment of climate change impacts and risks as well as adaptation is set against concurrently unfolding non-climatic global trends e.g., biodiversity loss, overall unsustainable consumption of natural resources, land and ecosystem degradation, rapid urbanisation, human demographic shifts, social and economic inequalities and a pandemic.

Working Group II introduces several new components in its latest report: These include the novel cross-chapter papers which provide focused assessments and updates from the special reports and include coverage of topics such as biodiversity hotspots, cities and settlements by the sea, deserts and desertification, mountains, tropical forests as well as the Mediterranean and polar regions. Another new component is an atlas that presents data and findings on observed climate change impacts and projected risks from global to regional scales, thus offering even more insights for decision makers. The Working Group II Report is based on the published scientific and technical literature accepted for publication by 1 September 2021.

Scope of the Report

During the process of scoping and approving the outline of its Sixth Assessment Report, the IPCC focussed on those aspects of the current knowledge of climate change that were judged to be most relevant to policymakers. In this report, Working Group II examines the impacts of climate change on nature and people around the globe. It explores future impacts at different levels of warming and the resulting risks, and offers options to strengthen nature's and society's resilience to ongoing climate change, to fight hunger, poverty, and inequality and keep Earth a place worth living on – for current as well as for future generations.

Structure of the Report

This report consists of a short Summary for Policymakers, a Technical Summary, eighteen Chapters, seven Cross-Chapter Papers, five Annexes including the Global to Regional Atlas, as well as online Supplementary Material.

The introductory chapter (Chapter 1) provides the reader with the framing and context of the report and highlights key concepts used throughout the report.

The sectoral chapters (Chapters 2–8) cover risks, adaptation and sustainability for systems impacted by climate change. They assess impacts, risks, adaptation options and limits and the interactions of risks and responses for climate resilient development for ecosystems, water, food, cities, human health, communities and livelihoods.

The regional chapters (Chapters 9–15) assess the observed impacts and projected risks at regional and sub-regional levels for Africa, Asia, Australasia, Central and South America, Europe, North America and Small Islands. They assess adaptation options including limits, barriers and adaptive capacity, as well as the interaction of risks and responses for climate resilient development.

The Cross-Chapter Papers (1–7) consider additional regionalisation's including polar regions, tropical forests, deserts, mountains and the Mediterranean, as well as highlighting the topics of biodiversity hotspots and cities by the sea. The cross-chapter papers assess observed impacts and projected risks of climate change, vulnerability, adaptation options and, where applicable, climate resilient development.

The synthesis chapters (Chapters 16–18) address sustainable development pathways integrating adaptation and mitigation. They assess key risks across sectors and regions (Chapter 16) and decision-making options for managing risk (Chapter 17) and the ways climate impacts and risks hinder climate resilient development in different sectoral and regional contexts as well as the pathways to achieving climate resilient development (Chapter 18).

The Process

This Working Group II contribution to the IPCC Sixth Assessment Report represents the combined efforts of hundreds of experts in the scientific, technological and socio-economic fields of climate science and has been prepared in accordance with rules and procedures established by the IPCC. A scoping meeting for the Sixth Assessment Report was held in May 2017 and the outlines for the contributions of the three Working Groups were approved at the 46th Session of the Panel in September 2017. Governments and IPCC observer organisations nominated experts for the author team. The team of 231 Coordinating Lead Authors and Lead Authors plus 39 Review Editors selected by the Working Group II Bureau was accepted at the 55th

Session of the IPCC Bureau in January 2018. In addition, more than 675 Contributing Authors provided draft text and information to the author teams at their request. Drafts prepared by the authors were subject to two rounds of formal review and revision followed by a final round of government comments on the Summary for Policymakers. A total of 62,418 written review comments were submitted by more than 1600 individual expert reviewers and 51 governments. The Review Editors for each chapter monitored the review process to ensure that all substantive review comments received appropriate consideration. The Summary for Policymakers was approved line-by-line and the underlying report was then accepted at the 12th Session of IPCC Working Group II from 14 to 27 February 2022.

Acknowledgements

We express our deepest appreciation for the expertise and commitment shown by the Coordinating Lead Authors and Lead Authors throughout the process. They were ably helped by the many Contributing Authors who supported the drafting of the report. The Review Editors were critical in assisting the author teams and ensuring the integrity of the review process. We are grateful to the Chapter Scientists who supported the chapter and cross-chapter paper teams in the delivery of the report. We would also like to thank all the expert and government reviewers who submitted comments on the drafts.

The production of the report was guided by members of the Working Group II Bureau. We would like to thank our colleagues who supported and advised us in the development of the report: Working Group II Vice-Chairs Andreas Fischlin, Mark Howden, Carlos Méndez, Joy Jacqueline Pereira, Roberto A. Sánchez-Rodríguez, Sergey Semenov, Pius Yanda, and Taha M. Zatari. Our appreciation also goes to Ko Barrett, Thelma Krug, and Youba Sokona, Vice Chairs of IPCC, who ably supported us during the planning process and approval.

Our sincere thanks go to the hosts and organizers of the Scoping Meeting, the four Lead Author Meetings, and the Working Group II Session. We gratefully acknowledge the support from the United Nations Economic Commission for Africa; the Government of South Africa and the Department of Forestry, Fisheries and the Environment; the Government of Nepal and the International Centre for Integrated Mountain Development; the Government of Portugal, the Center for Marine Sciences, and the University of Algarve; the Government of Guatemala and the Ministry of Environment and Natural Resources;

and the Government of Germany. We also note with appreciation the additional support for inclusivity training provided by the International Centre for Integrated Mountain Development. The support provided by many governments as well as through the IPCC Trust Fund for the many experts participating in the process is also noted with appreciation.

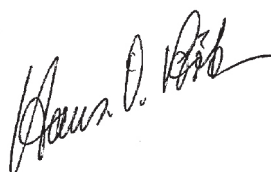
The staff of the IPCC Secretariat based in Geneva provided a wide range of support for which we would like to thank Abdalah Mokssit, Secretary of the IPCC, Deputy Secretaries, Ermira Fida and Kerstin Stendahl, and their colleagues Jesbin Baidya, Laura Biagioni, Annie Courtin, Oksana Ekzarkho, Judith Ewa, Joelle Fernandez, Jennifer Lew Schneider, Jonathan Lynn, Andrej Mahecic, Nina Peeva, Sophie Schlingemann, Mxolisi Shongwe, Melissa Walsh, and Werani Zabula.

The report production was managed by the Technical Support Unit of IPCC Working Group II, through the generous financial support of the German Federal Ministry for Education and Research and the Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research. Additional funding from the Governments of Germany, Norway and New Zealand supports the Working Group II Technical Support Unit office in Durban, South Africa. Without the support of all these bodies this report would not have been possible.

This Report could not have been prepared without the dedication, commitment, and professionalism of the members of the Working Group II Technical Support Unit and Science Advisor: Melinda Tignor, Elvira Poloczanska, Katja Mintenbeck, Andrés Alegría, Marlies Craig, Sandra Götze, Tijama Kersher, Stefanie Langsdorf, Sina Lösckke, Philisiwe Manqele, Vincent Möller, Anka Mühle, Komila Nabiyeva, Almut Niebuhr, Andrew Okem, Esté Prentzler, Bardhyl Rama, Jussi Savolainen, and Stefan Weisfeld. Additional contributions from Daniel Belling, Wolfgang Dieck, Bastian Maus, Maike Nicolai, Jan Petzold, Hanna Scheuffele, and Nora Weyer are recalled with appreciation. The support provided by Nina Hunter and Michelle North is also recognized.

Our warmest thanks go to the collegial and collaborative support provided by Working Group I and Working Group III Co-Chairs, Vice-Chairs and Technical Support Units. In addition, the following contributions are gratefully acknowledged: le-tex publishing services GmbH (copyedit and layout), Marilyn Anderson (index).

And a final, special thank you to the colleagues, family and friends who supported us through the many long hours and days spent at home and away from home while producing this report.



Hans-Otto Pörtner
IPCC Working Group II Co-Chair



Debra C. Roberts
IPCC Working Group II Co-Chair

Dedication



Bob (Robert) Scholes
(28 October 1957 – 28 April 2021)

The chapter on Africa of the Working Group II Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), is dedicated to the memory of Bob Scholes who was one of the Review Editors for the chapter.

Bob, one of the world's leading climate change scientists, was a Professor of Systems Ecology, a Director of the Global Change Institute and a Distinguished Professor at the University of the Witwatersrand in Johannesburg, South Africa. Known for his towering intellect and insatiable curiosity, Bob published widely in the fields of savanna ecology, earth observation and global change. As a well-respected member of the global research community he played a major role in the IPCC as a Lead Author and Co-ordinating Lead Author during the third, fourth and fifth assessment cycles and as Co-Chair of the IPBES Land Degradation and Ecosystem Assessment. He was also a leading figure in African scientific circles and undertook multidisciplinary research to support policy development, risk assessment and development planning in South Africa and on the continent.

Bob was acutely aware of the need to build a more equitable and just society and was always generous with his knowledge and wisdom. He will be remembered as a remarkable role model, inspirational teacher and a thoughtful mentor to both students and colleagues. He was a son of African soil and dedicated much of his life to preserving Africa's natural heritage for future generations. But he was also at home anywhere on Earth – truly a person of the planet. Bob lived life to its fullest, as was evident in his love of gourmet cooking.

Bob's loss is felt deeply by all who knew him, and he will be remembered as a multi-talented and passionate scientist who motivated everyone to avoid complacency, think critically and to use their knowledge to improve the world.

Hamba kahle Bob.



Rebecca Mary Bernadette Harris
(01 August 1969 – 24 December 2021)

Chapter 2, 'Terrestrial and freshwater ecosystems and their services', and Cross-Chapter Paper 3, 'Deserts, semi-arid areas and desertification' of the Working Group II contribution to the IPCC Sixth Assessment Report are dedicated to the memory of Rebecca Harris, who was one of the Lead Authors.

Bec was the Director of the Climate Futures Program at the University of Tasmania. This award-winning team is globally recognised for its impacts and adaptation work including for the skiing and wine industries, biosecurity threats to agriculture, and what climate change meant for Tasmanian fire management. Bec helped both government and industry partners better assess their exposure to climate risk, and develop adaptation solutions. A highlight is the work that she launched in 2020: *Australia's Wine Future: A Climate Atlas*. Bec oversaw this multidisciplinary climate modelling and adaptation project (2016-2020) involving 15 researchers from six organisations, bringing national recognition to her work.

Prior to starting her PhD studies relatively late in life, Bec worked in invertebrate and botanical biodiversity assessment, island biogeography and disturbance ecology. In the short decade-long research career, Bec authored 66 publications, won numerous research contracts and consultancy projects and in 2016 was awarded a prestigious Humboldt Fellowship.

Bec also supervised many honours and PhD students over the last decade and was a mentor and sponsor for many early career researchers. She was particularly passionate about supporting women in science. She was an inspiring lecturer and was also committed to enhancing community climate literacy as an avenue for making change. She had a talent for translating the complex science work she undertook for non-expert audiences in a way that was clear and impactful.

As a researcher and scholar, Bec is an exemplar, and she will be very sorely missed.

