

GEO6

GLOBAL ENVIRONMENT OUTLOOK

HEALTHY
PLANET
HEALTHY
PEOPLE

UN 
environment
United Nations
Environment Programme



CAMBRIDGE

GLOBAL ENVIRONMENT OUTLOOK
GEO-6
HEALTHY PLANET, HEALTHY PEOPLE

University Printing House, Cambridge CB2 8BS, United Kingdom
One Liberty Plaza, 20th Floor, New York, NY 10006, USA
477 Williamstown Road, Port Melbourne, VIC 3207, Australia
314–321, 3rd Floor, Plot 3, Splendor Forum, Jasola District Centre, New Delhi – 110025, India
79 Anson Road, #06–04/06, Singapore 079906

Cambridge University Press is part of the University of Cambridge.
It furthers the University's mission by disseminating knowledge in the pursuit of
education, learning and research at the highest international levels of excellence.

www.cambridge.org
Information on this title: www.cambridge.org/9781108707664
DOI: 10.1017/9781108627146

© UN Environment 2019
First published 2019

This publication may be reproduced in whole or in part and in any form for educational or non-profit services
without special permission from the copyright holder, provided acknowledgement of the source is made.
UN Environment would appreciate receiving a copy of any publication that uses this publication as a source.

An online version of this work is published at doi.org/10.1017/9781108627146 under a Creative Commons
Open Access license CC-BY-NC-ND 4.0 which permits re-use, distribution and reproduction in any medium for
non-commercial purposes providing appropriate credit to the original work is given. You may not distribute
derivative works without permission. To view a copy of this license, visit <https://creativecommons.org/licenses/by-nc-nd/4.0>

No use of this publication may be made for resale or any other commercial purpose whatsoever without
prior permission in writing from UN Environment. Applications for such permission, with a statement of the
purpose and extent of the reproduction, should be addressed to the Director, Communication Division,
UN Environment, P. O. Box 30552, Nairobi 00100, Kenya.

All versions of this work may contain content reproduced under license from third parties.
Permission to reproduce this third-party content must be obtained from these third-parties directly.

The designations employed and the presentation of the material in this publication do not imply the
expression of any opinion whatsoever on the part of UN Environment concerning the legal status of any
country, territory or city or its authorities, or concerning the delimitation of its frontiers or boundaries. For
general guidance on matters relating to the use of maps in publications please go to
<http://www.un.org/Depts/Cartographic/english/htmain.htm>

This document may be cited as: UN Environment (2019). Global Environment Outlook – GEO-6: Healthy
Planet, Healthy People. Nairobi. DOI 10.1017/9781108627146.

Job Number: DEW/2214/NA
© Maps, photos, and illustrations as specified
Cover design: Joseph Schmidt-Klingenberg and Sebastian Obermeyer
Graphic Design: Joseph & Sebastian
Layout: Jennifer Odallo and Catherine Kimeu (UNON Publishing Services Section – ISO 14001-certified)

Printed in Singapore by Markono Print Media Pte Ltd

A catalogue record for this publication is available from the British Library.
ISBN 978-1-108-70766-4 Paperback

Disclaimers

Mention of a commercial company or product in this document does
not imply endorsement by UN Environment or the authors. The use
of information from this document for publicity or advertising is not
permitted. Trademark names and symbols are used in an editorial fashion
with no intention on infringement of trademark or copyright laws.

Cambridge University Press has no responsibility for the persistence or
accuracy of URLs for external or third-party internet websites referred
to in this publication, and does not guarantee that any content on such
websites is, or will remain, accurate or appropriate.

UN Environment
promotes environmentally
sound practices globally and in its own
activities. This report is printed on Forest
Stewardship Council (FSC) certified paper from
sustainable forests with non-toxic inks.
Our distribution policy aims to reduce
UN Environment's carbon footprint.

GLOBAL ENVIRONMENT OUTLOOK
GEO-6
HEALTHY PLANET, HEALTHY PEOPLE



A healthy planet is important for the health and well-being of all people. It directly supports the lives and livelihoods of 70 per cent of the Earth's population

The top 10 emitting countries emit 45 per cent of global GHG emissions; the bottom 50 per cent emit only 13 per cent

Exposure to indoor/outdoor air and water pollution costs at least 9 million lives annually



Current science justifies policy action now. More detailed knowledge can enable more refined and ambitious policy

Achieving the 2°C Paris Agreement target could save US\$ 54.1 trillion for a global expenditure of \$US 22.1 trillion. Achieving a 1.5°C target could lead to a health saving of \$US 3.3-8.4 trillion for India and \$US 0.3-2.3 trillion for China

Meat production currently uses 77 per cent of agricultural land. Agricultural production consumes 70 per cent of global water.

Acknowledgements

The sixth Global Environment Outlook (GEO-6) assessment report is a product of the generous dedication and extraordinary investment of numerous individuals, whose knowledge, expertise and insight helped shape this important body of work. UN Environment acknowledges the contributions made by many governments, individuals and institutions to the preparation and publication of this report. A more complete list of names of individuals and institutions involved in the assessment process is included following the annexes of this publication. Special thanks are extended to:

High Level Inter-Governmental and Stakeholder Advisory Group (HLG)

Nassir S. Al-Amri, Hæge Andenæs, Juan Carlos Arredondo, Sara Baisai Feresu, Benon Bibbu Yassin, Simon Birkett, Gillian Bowser, Joji Carino, Fernando E.L.S. Coimbra, Marine Collignon (alternate), Victoria de Higa Rodriguez, Laksmi Dhewanthi, Noasilalaonomenjahary Ambinintsoa Lucie, Arturo Flores Martinez (alternate), Sascha Gabizon, Prudence Galega, Edgar Gutiérrez Espeleta, Keri Holland (alternate), Pascal Valentin Houénou (Vice-chair), Yi Huang (Co-chair), Ingeborg Mork-Knutsen (alternate), Melinda Kimble, Asdaporn Krairapanond, Yaseen M. Khayyat, Pierluigi Manzione, Veronica Marques (alternate), Jock Martin, John M. Matuszak, Megan Meaney, Naser Moghaddasi, Bedrich Moldan, Roger Roberge, Najib Saab, Mohammed Salahuddin, Jurgis Sapijanskas (alternate), Paolo Soprano (Co-chair), Xavier Sticker, Sibylle Vermont (Vice-chair), Andrea Vincent (alternate), Terry Yosie.

Scientific Advisory Panel

Asma Abahussain, John B.R. Agard, Odeh Al-Jayyousi, Paulo Eduardo Artaxo Netto, Rosina M. Bierbaum, Enrico Giovannini, Sarah Green (Co-chair), Torkil Jørch Clausen, Ahmed Khater, Nicholas King (Co-chair), Paolo Laj, Byung-Kook Lee, Alastair Charles Lewis, Franklyn Lisk, Majid Shafiepour Motlagh, Carlos Afonso Nobre, Toral Patel-Weynand, Anand Patwardhan, N.H. Ravindranath (Vice-chair), Wedelin Stark, Danling Tang, Maria del Mar Viana Rodriguez (Vice-chair), Naohiro Yoshida.

Members of the Assessment Methodologies, Data and Information Working Group

Maria Andrzejewska, Ousséni Arouna, Sandra De Carlo (Co-chair), Rosario Gomez, Wabi Marcos, Reza Maknoon, Graciela Metternicht, Thy Nguyen Van, Nicolas Perritaz (Co-chair), Qurat ul Ain Ahmad, Mathis Wackernagel, Fei Wang.

Co-chairs and Vice-chairs of the assessment

Co-chairs: Paul Ekins, Joyeeta Gupta.

Vice-chairs: Jane Bemigisha, Kejun Jiang.

Coordinating Lead Authors (CLAs)

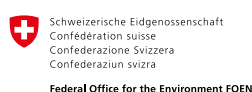
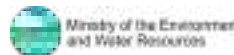
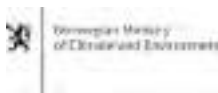
Ghassem Asrar, Elaine Baker, Tariq Banuri, Graeme Clark, John Crump, Florence Mayocyc-Daguitan, Jonathan Davies, Phillip Dickerson, Nicolai Dronin, Mark Elder, Erica Gaddis, Jia Gensuo, Anna Maria Grobicki, Cristina Guerreiro, Andrés Guhl, Peter Harris, Rowena Hay, Steve Hedden, Klaus Jacob, Mikiko Kainuma, Terry Keating, Peter King, Pali Lehohla, Christian Loewe, Paul Lucas, Diana Mangalagiu, Diego Martino, Shanna McClain, Catherine McMullen, Adelina Mensah, Indu K. Murthy, Charles Mwangi, John Muthama Nzioka, Jacob Park, Laura Pereira, Fernando Figueira Prates, Walter Rast, Jake Rice, Joni Seager, William Sonntag, Peter Stoett, Michelle Tan, Detlef van Vuuren, Dimitri Alexis Zenghelis.

Review Editors

Amr Osama Abdel-Aziz, Ahmed Abdelrehim, Majdah Aburas, Mohammad Al Ahmad, Chandani Appadoo, Michael Brody, Louis Cassar, William W. Dougherty, Manal Elewah, Amr El-Sammak, Elsa Patricia, Galarza Contreras, Jose Holguin-Veras, Muhammad Ijaz, Joy Jadam, Emmanuel Dieudonné Kam Yogo, Yoon Lee, Clever Mafuta, Simone Maynard, Joan Momanyi, Jacques André Ndione, Washington Odongo Ochola, Renat Perelet, Linn Persson, Jan Plesnik, Ariana Rossen, Mayar Sabet, John Shilling, Binaya Raj Shivakoti, Asha Singh, Asha Sitati, Lawrence Surendra, Paul C. Sutton, Khulood Abdul Razzaq Tubaishat, Emma Archer van Garderen, Lei Yu, Samy Mohamed Zalat.

GEO-6 Funders

Producing an assessment of this scale requires many generous contributions. The following organizations provided funding directly or indirectly to the sixth *Global Environment Outlook*: The Government of Norway, the European Union, the Governments of Italy, Singapore, China, Mexico, Switzerland, Denmark, Egypt and Thailand. Together with UN Environment's Environment Fund and Regular Budget, these contributions allowed for the production of GEO-6 and its accompanying Summary for Policymakers, as well as subsequent outreach activities.



GEO-6 Partners

GEO-6 also benefited from the generous contributions of several partners, including: GRID-Arendal, World Conservation Monitoring Centre (WCMC), The Centre for Environment and Development in the Arab Region and Europe (CEDARE), The Big Earth Data Science Engineering Program (CASEarth), the European Space Agency (ESA), the Netherlands Environmental Assessment Agency (PBL), the Freie Universität Berlin and the Massachusetts Institute of Technology (MIT).



The sixth Global Environment Outlook Production Team

GEO-6 Core Team

Pierre Boileau (Head of GEO Unit), Minang Acharya, Yunting Duan, Sandor Frigyik, Orlane Jadeau, Caroline Kaimuru, Jian Liu, Caroline Mureithi, Franklin Odhiambo, Brigitte Ohanga, Adele Roccato, Sharif Shawky, Simone Targetti Ferri, Brennan Van Dyke, Edoardo Zandri.

Chapter Coordinators

Joana Akrofi, Hilary Allison, Jennifer Bailey, Pierre Boileau, Jillian Campbell, Kilian Christ, John Crump, Valentin Foltescu, Jason Jabbour, Hartwig Kremer, Maarten Kappelle, Patrick M'Mayi, Franklin Odhiambo, Mohamed Sessay, Michael Stanley-Jones, Simone Targetti Ferri, Kaisa Uusimaa, Clarice Wilson.

Production and Data Support

Misha Alberizzi, Matthew Billot, Alexandre Caldas, Jillian Campbell, Ludgarde Coppens, Ananda Dias, Angeline Djampou, Dany Ghafari, Virginia Gitari, Florence Kahi, Isabell Kempf, Sera Kinoyan, Ian Magero, Nada Matta, Pascal Muchesia, Josephine Mule, Jane Mureithi, Theuri Mwangi, Immaculate Mwololo, Samuel Opiyo, Audrey Ringler, Jinhua Zhang.

Peer-review System and Database

Ahmed Abdelrehim (CEDARE), Tesfaye Demissie (UNECA), Clever Mafuta (GRID-Arendal), Mayar Sabet (CEDARE), Ayman Soliman (CEDARE), Viola Sawiris (CEDARE), Youssef Younis (CEDARE).

Maps and Graphics

Fang Chen (CASEarth/RADI), Pouran Ghaffarpour (UNON Publishing), Catherine Kimeu (UNON Publishing), Samuel Kinyanjui (UNON Publishing), Jie Liu (CASEarth/RADI), Jennifer Odallo (UNON Publishing), Audrey Ringler, Jinita Shah (UNON Publishing), Zeeshan Shirazi (CASEarth/RADI), Lei Wang (CASEarth/RADI).

Editorial Team

Markus MacGill (Green Ink Limited), Clare Pedrick (Green Ink Limited), Anne Sweetmore (Green Ink Limited), Tim Woods (Green Ink Limited).

Design and Layout

Jennifer Odallo, Catherine Kimeu (UNON Publishing Services Section), Audrey Ringler (UN Environment)

Table of contents

Acknowledgements	vi
Secretary-General's Foreword	xxvi
Acting UN Environment Executive Director's Foreword	xxvii
Co-Chairs' Foreword	xxviii
Co-Chairs' Message	xxix

SETTING THE STAGE



CHAPTER 1: Introduction and Context	03
1.1 GEO-6 healthy planet, healthy people – humanity's transformative challenge	03
1.2 UNEP's flagship assessment to deliver the environmental dimension of the 2030 agenda	07
1.3 GEO-6 in a changing global context	08
1.4 Environmental governance	11
1.5 The environmental dimension of the sustainable development goals, global environmental governance and multilateral environmental agreements	11
1.6 GEO-6 in the context of other environmental assessments	12
1.7 GEO-6 approach, theory of change and structure	13
References	17



CHAPTER 2: Drivers of Environmental Change	21
Executive summary	22
2.1 Introduction and context	24
2.2 Changes since the last assessment	24
2.3 Population	25
2.4 Urbanization	31
2.5 Economic development	36
2.6 Technology, innovation, and global sustainability	40
2.7 Climate change	43
2.8 Unravelling drivers and their interactions	48
References	52



CHAPTER 3: The Current State of our Data and Knowledge	57
Executive summary	58
3.1 Introduction	59
3.2 The demand for environmental statistics and data	59
3.3 History of environmental statistics	59
3.4 Better data for a healthy planet with healthy people	60
3.5 Gender and social-environment intersectionality	64
3.6 Equity and human-environment interactions	66
3.7 Existing data systems	68
3.8 Conclusion	71
References	72



CHAPTER 4: Cross-cutting Issues	75
Executive summary	76
4.1 Introduction	78
4.2 People and livelihoods	78
4.3 Changing environments	85
4.4 Resources and materials	91
4.5 Conclusions	97
References	98

PART A: STATE OF THE GLOBAL ENVIRONMENT



CHAPTER 5: Air 107

Executive summary.....	108
5.1 Introduction.....	109
5.2 Pressures: emissions.....	110
5.3 State: atmospheric composition and climate.....	117
5.4 Impacts.....	125
5.5 Response: policies and governance.....	129
References.....	134



CHAPTER 6: Biodiversity 141

Executive summary.....	142
6.1 Introduction.....	144
6.2 Further assessments since the fifth Global Environmental Outlook (GEO-5).....	145
6.3 Drivers.....	146
6.4 Pressures.....	146
6.5 Global state and trends of biodiversity.....	153
6.6 Impacts on the world's biomes.....	158
6.7 Responses.....	164
6.8 Conclusion.....	167
References.....	168



CHAPTER 7: Oceans and Coasts 175

Executive summary.....	176
7.1 Introduction.....	178
7.2 Pressures.....	180
7.3 State.....	181
7.4 Impacts.....	186
7.5 Response.....	191
7.6 Conclusions.....	193
References.....	195



CHAPTER 8: Land and Soil 201

Executive summary.....	202
8.1 Land resources and the sustainable development goals.....	204
8.2 Setting the stage for GEO-6: the GEO-5 legacy.....	204
8.3 Drivers and pressures.....	204
8.4 Key state and trends.....	209
8.5 Key impacts.....	217
8.6 Policy responses.....	224
References.....	229



CHAPTER 9: Freshwater 235

Executive summary.....	236
9.1 Introduction and priority issues.....	238
9.2 Pressures on freshwater.....	238
9.3 Water and land use.....	240
9.4 Global state and trends of freshwater.....	240
9.5 Water quality.....	244
9.6 Freshwater ecosystems.....	250
9.7 Water infrastructure.....	252
9.8 Impacts.....	255
9.9 Policy responses.....	257
9.10 Conclusions.....	263
References.....	265

PART B: POLICIES, GOALS, OBJECTIVES AND ENVIRONMENTAL GOVERNANCE: AN ASSESSMENT OF THEIR EFFECTIVENESS



CHAPTER 10: Approach to Assessment of Policy Effectiveness	273
10.1 The Context	274
10.2 Environmental policy and governance	274
10.3 Policy instruments	275
10.4 Policy mixes and coherence	275
10.5 Methodology adopted to assess policy effectiveness	277
10.6 Top-down evaluation methodology	278
10.7 Bottom-up evaluation methodology	279
10.8 Content of Part B	280
References	281



CHAPTER 11: Policy Theory and Practice	283
Executive summary	284
11.1 Introduction	285
11.2 Policy design	285
11.3 Policy integration	289
11.4 Effectiveness of international and multilevel governance	294
11.5 Conclusions	296
References	297



CHAPTER 12: Air Policy	301
Executive summary	302
12.1 Introduction	303
12.2 Key policies and governance approaches	303
12.3 Indicators	315
12.4 Discussion and conclusions	319
References	320



CHAPTER 13: Biodiversity Policy	323
Executive summary	324
13.1 Introduction	325
13.2 Key policies and governance approaches	326
13.3 Indicators: Biodiversity policy	338
13.4 Conclusions	342
References	344



CHAPTER 14: Oceans and Coastal Policy	349
Executive summary	350
14.1 Introduction	351
14.2 Key policies and governance approaches	351
14.3 Indicators	362
14.4 Discussion and conclusions	366
References	367



CHAPTER 15: Land and Soil Policy	373
Executive summary	374
15.1 Introduction	376
15.2 Key policies and governance approaches	377
15.3 Indicators	389
15.4 Conclusions	393
References	394



CHAPTER 16: Freshwater Policy	399
Executive summary	400
16.1 Introduction	401
16.2 Key policies and governance approaches	401
16.3 Indicators (link to SDGs and MEAs)	412
16.4 Discussion and conclusions	419
References	420



CHAPTER 17: Systemic Policy Approaches for Cross-cutting Issues	425
Executive summary	426
17.1 Cross-cutting policy issues and systemic change	428
17.2 Key actors, policies and governance approaches	428
17.3 Adapting socioeconomic systems to be more resilient to climate change	429
17.4 Creating a sustainable agrifood system	432
17.5 Indicators	435
17.6 Decarbonizing energy systems	436
17.7 Towards a more circular economy	439
17.8 Conclusions	446
References	448



CHAPTER 18: Conclusions on Policy Effectiveness	453
18.1 Overview of the outcomes	454
18.2 Connections to future policy	456
18.3 Gaps in knowledge	456
18.4 Key lessons from the analysis	457
References	458

PART C: OUTLOOKS AND PATHWAYS TO A HEALTHY PLANET WITH HEALTHY PEOPLE



CHAPTER 19: Outlooks in GEO-6	463
Executive summary	464
19.1 Introduction	465
19.2 Important elements of future-oriented environmental outlooks	465
19.3 A new framework for combining top-down and bottom-up analysis methods	466
19.4 The role of scale	467
19.5 Roadmap for Part C of GEO-6	467
References	469



CHAPTER 20: A Long-Term Vision for 2050	471
Executive summary	472
20.1 Introduction	473
20.2 The environmental dimension of the SDGs	473
20.3 An integrated view on the SDGs	473
20.4 A long-term vision: selected targets and indicators	476
20.5 Conclusions	481
References	482



CHAPTER 21: Future Developments Without Targeted Policies	485
Executive summary	486
21.1 Introduction	488
21.2 Global environmental scenarios	488
21.3 The achievement of SDGs and related MEAs in trend scenarios	490
21.4 Are we achieving the targets?	502
References	506



CHAPTER 22: Pathways Toward Sustainable Development	511
Executive summary	512
22.1 Introduction	514
22.2 Pathways definition	514
22.3 Pathways towards achieving the targets	514
22.4 An integrated approach	532
22.5 Conclusions and recommendations	537
References	539

**CHAPTER 23: Bottom-up Initiatives and Participatory Approaches for Outlooks.....545**

Executive summary.....	546
23.1 Introduction.....	548
23.2 Integrating global assessments and bottom-up analyses.....	548
23.3 Sub-global assessments in a multilevel context.....	549
23.4 Bottom-up futures based on existing local practices.....	550
23.5 Methodological rationale and approach.....	550
23.6 Investigating the broad landscape of bottom-up initiatives.....	551
23.7 GEO-6 participatory initiatives.....	552
23.8 GEO-6 Regional Assessments.....	553
23.9 Findings from a bottom-up approach.....	553
23.10 GEO Regional Assessment synthesis.....	566
23.11 Regional outlook interventions and bottom-up initiatives.....	570
23.12 Enabling conditions for transformations.....	572
23.13 Key messages.....	573
23.14 Key interventions and a critical need to recognize distributive justice given global inequities and inequality.....	576
References.....	577

**CHAPTER 24: The Way Forward.....581**

Executive summary.....	582
24.1 Approaches for environmental policy: strategic and transformative.....	583
24.2 Transformative change.....	584
24.3 Building blocks for transformation.....	584
24.4 Healthy planet, healthy people: challenge and opportunity.....	587
References.....	590

PART D: REMAINING DATA AND KNOWLEDGE GAPS**CHAPTER 25: Future Data and Knowledge Needs.....597**

Executive summary.....	598
25.1 Introduction.....	599
25.2 Emerging tools for environmental assessment.....	599
25.3 Environmental monitoring for the future.....	612
25.4 Conclusion: challenges, gaps and opportunities.....	615
References.....	618

**ANNEXES.....619**

Annex 1-1: Mission of the sixth Global Environment Outlook.....	620
Annex 1-2: Range of integrated environmental assessments which the sixth Global Environment Outlook draws from.....	621
Annex 1-3: Theory of Change for the sixth Global Environment Outlook (GEO-6).....	623
Annex 1-4: Structure and rationale for confidence statements used in the sixth Global Environment Outlook.....	625
Annex 4-1: Towards monitoring the environmental dimension of the SDGs.....	629
Annex 6-1: The principal biodiversity-related Conventions.....	637
Annex 9-1: Water contaminants and occurrences.....	638
Annex 13-1: Biodiversity conservation and International Environmental Agreements (IEAs).....	641
Annex 13-2: Overview of key policy developments and governance responses at a global level.....	642
Annex 23-1: Bottom-up Initiative platforms and results.....	643

**THE GEO-6 PROCESS.....661**

Timeline.....	664
Partnerships and collaboration.....	665
Review process.....	665
GEO-6 Advisory bodies.....	666
Consultation process.....	666
GEO-6 Author teams.....	675

Figures

Introduction and Context

Figure 1.1:	Choices to be made to achieve a healthy planet for healthy people.	06
Figure 1.2:	The DPSIR approach used in GEO-6.	13
Figure 1.3:	Structure of GEO-6, with a link to its Theory of Change (see Annex 1-3).	15

Drivers of Environmental Change

Figure 2.1:	World population, emissions and fertility.	26
Figure 2.2:	Emissions per capita according to demographics.	27
Figure 2.3:	Projected world population.	28
Figure 2.4:	Consumption and associated environmental pressures are unequally distributed between nations.	29
Figure 2.5:	World population distribution and composition.	30
Figure 2.6:	Contraceptive prevalence and total fertility.	30
Figure 2.7:	Female secondary education and total fertility rates.	31
Figure 2.8:	Global urban population growth propelled by cities.	32
Figure 2.9:	City growth rates.	32
Figure 2.10:	Where rapid growth faces high vulnerability.	34
Figure 2.11:	Built-up area vs. Population (1975-2015).	35
Figure 2.12:	How growth rates in developing countries began outstripping those in developed countries.	37
Figure 2.13:	World trade growth.	38
Figure 2.14:	Milanovic's elephant curve.	39
Figure 2.15:	Industry 4.0: technological transformation of future industrial production.	43
Figure 2.16:	Mean atmospheric CO ₂ concentration.	43
Figure 2.17:	Global growth in emissions of GHGs by economic region.	44
Figure 2.18:	Emission trends in different countries from 1990-2015.	45
Figure 2.19:	The carbon crunch.	45
Figure 2.20:	Multiple independent indicators of a changing global climate.	46
Figure 2.21:	The enhanced burning embers diagram, providing a global perspective on climate-related risks.	47
Figure 2.22:	Trends in numbers of loss-relevant natural events.	48
Figure 2.23:	Relationship across the drivers.	50

The Current State of our Data and Knowledge

Figure 3.1:	SDGs data and knowledge framework.	60
Figure 3.2:	SDG indicator status.	60
Figure 3.3:	Environment-related SDG indicators by goal and tier.	61
Figure 3.4:	GEO-6 major data gaps organized by respective chapter.	61
Figure 3.5:	Unpaid care work.	65
Figure 3.6:	Equity questions in data and knowledge.	66

Cross-cutting Issues

Figure 4.1:	The economic and human impact of disasters in the last ten years.	80
Figure 4.2:	Percentage distribution of the water collection burden across 61 countries.	81
Figure 4.3:	Key competencies and performance of sustainability citizens.	82
Figure 4.4:	World urbanization trends.	84
Figure 4.5:	Global annual average temperature anomalies (relative to the long-term average for 1981-2010). Labelling designates different data sets; for explanation refer to the source.	85
Figure 4.6:	Arctic sea ice age and extent.	87
Figure 4.7:	Chemical intensification, 1955-2015.	88
Figure 4.8:	Global illegal waste traffic.	90
Figure 4.9:	West Asia non-conventional annual water resources.	91
Figure 4.10:	Example of ore grade decline over time for copper mining, showing world annual copper production and estimated tailings generated annually.	92
Figure 4.11:	Technology wedges to achieve the 2°C pathway.	94
Figure 4.12:	Ranges of levelized cost of electricity for different renewable power generation technologies, 2014 and 2025.	94
Figure 4.13:	The subglobal distributions and current status of the control variables for (A) biogeochemical flows of phosphorus; (B) biogeochemical flows of nitrogen.	96

Air

Figure 5.1:	Primary linkages between pressures, state and impacts of atmospheric change.	109
Figure 5.2:	Linkages between changes in atmospheric composition and achievement of the Sustainable Development Goals.	110
Figure 5.3:	Annual emission trends from 1990 to 2014 in kilotons by pollutant, region and sector.	111
Figure 5.3	(continued): Annual emission trends from 1990 to 2014 in kilotons by pollutant, region and sector.	112
Figure 5.3	(continued): Annual emission trends from 1990 to 2014 in kilotons by pollutant, region and sector.	113
Figure 5.4:	Global fuel shares of electricity generation in 2015 ¹ .	113

Figure 5.5:	World petroleum refinery output by-product (million tons).....	114
Figure 5.6:	World electricity generation by fuel (terawatt hours) ¹	114
Figure 5.7:	Annual average PM _{2.5} concentrations in 2016 compared with the WHO Air Quality guideline and interim targets.	118
Figure 5.8:	Seasonal average population-weighted O ₃ concentration in 2016 for season with maximum ozone levels by country.	119
Figure 5.9:	Annual average PM ₁₀ levels for megacities of more than 14 million inhabitants with available data for the period 2011-2015.	119
Figure 5.10:	Model estimates of the sources of PM _{2.5} observed in several cities in each of three countries shows local PM _{2.5} concentrations are strongly influenced by secondary particles from transboundary sources. The source of emissions is divided into natural, international (emitted outside the country), national (emitted within the country but outside the urban area), urban (emitted within the city) and street (emitted within the immediate vicinity of the observation) and interim targets.	120
Figure 5.11:	The Dust Belt.	121
Figure 5.12:	Global distribution of annual mean gaseous elemental mercury concentration in near-surface air (top) and wet-deposition flux (bottom) in 2015 simulated by a model ensemble.	122
Figure 5.13:	Vertical profiles of annual mean O ₃ trends over 35°-60°N averaged over all available observations (black) for the periods of stratospheric ODS increase (left) and ODS decline (right), with the corresponding modelled trends for ODS changes only (red), GHG changes only (blue) and both together (grey).	123
Figure 5.14:	Deaths per 100,000 people in 2016 attributable to ambient PM _{2.5} air pollution; age-standardized data.	126
Figure 5.15:	Percentage of PM _{2.5} related deaths in a region indicated by the column due to (a) emissions produced or (b) goods and services consumed in the region indicated by the row.	127
Figure 5.16:	Map of groupings of selected regional multilateral air pollution agreements.	131

Biodiversity

Figure 6.1:	Schematic from the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services describing the main elements and relationships linking nature, biodiversity and ecosystem services, human well-being and sustainable development. (In this diagram, anthropogenic drivers equate to the pressures as described in Section 6.3.).....	144
Figure 6.2:	Interconnections between people, biodiversity, ecosystem health and provision of ecosystem services showing drivers and pressures.	146
Figure 6.3:	Examples of global distribution of pressures on (a) threat intensity (H: high; L: low; M: medium; VH: very high; VL: very low) from terrestrial invasive alien species and (b) cumulative fisheries by-catch intensity for seabirds, sea mammals and sea turtles, by all gear types (gillnet, longline and trawl).	147
Figure 6.4:	Percentage of threatened (critically endangered, endangered and vulnerable) and near threatened amphibian, bird and mammal species by major threat class.	148
Figure 6.5:	Map of the global human footprint for 2009 (combined pressures of infrastructure, land cover and human access into natural areas, using a 0-50 on a cool to hot colour scales) (a), and absolute change in average human footprint from 1993 to 2009 at the ecoregion scale (b).	149
Figure 6.6:	Impact mechanism of invasive alien species on threatened species in Europe.	150
Figure 6.7:	Recorded number of rhinoceros poached in South Africa, 2007-2015. In 2011, the rhino population in South Africa numbered just over 20,000.	151
Figure 6.8:	Global map showing species vulnerable to climate change.	152
Figure 6.9:	Proportions of local animal breeds, classified as being at risk, not at risk or unknown level of risk of extinction.	153
Figure 6.10:	Cumulative number of species with whole genome sequences (2000-2016).	154
Figure 6.11:	The proportion of species in each extinction risk category of the IUCN Red List of Threatened Species.	155
Figure 6.12:	Red List Index of species survival for birds, mammals, amphibians, corals and cycads, and an aggregate (in blue) for all species.	155
Figure 6.13:	Global Living Planet Index.	156
Figure 6.14:	Terrestrial Biodiversity Intactness Index.	156
Figure 6.15:	Mechanisms of ecosystem collapse, and symptoms of the risk of collapse.	157
Figure 6.16:	Mean percentage change in each broad habitat type based on satellite imagery: (a) change from original land-cover type between 2001 and 2012; (b) vegetation productivity as measured using the Enhanced Vegetation Index between the years 2000-2004 and 2009-2013.	158
Figure 6.17:	Global trends in the state of the world's marine stocks 1975-2015.	159
Figure 6.18:	Extinction risk of global freshwater fauna by taxonomic group.	160
Figure 6.19:	Capacity of mountains to provide ecosystem services.	163
Figure 6.20:	Protected areas of the world.	165

Oceans and Coasts

Figure 7.1:	Generalized schematic showing the drivers and pressures relevant to the marine environment.	179
Figure 7.2:	Map showing the maximum heat stress during the ongoing 2014-17 global coral bleaching event.	181
Figure 7.3:	World capture fisheries and aquaculture production.	182
Figure 7.4:	Status of fish stocks and fishing mortality as influenced by various factors of science, management and governance. Higher relative scores on vertical axis reflect better stock status relative to theoretically 'ideal' management.	183

Figure 7.5:	Biomagnification and bioaccumulation of methylmercury in the food chain.	185
Figure 7.6:	Global map of potential marine plastic input to the oceans based on human activities and watershed characteristics.	186
Figure 7.7:	Plastic litter in the open ocean.	188

Land and Soil

Figure 8.1:	Different perspectives on the globalization of lands in 2007 (Exckert IV projection).	206
Figure 8.2:	Relative roles played by agricultural commodities versus manufactures and services in globalizing lands (Eckert IV projections).	207
Figure 8.3:	Estimated net impact of climate trends for 1980-2008 on crop yields by country.	208
Figure 8.4:	Changes of global forests (a) and cropland (b) 1992-2015 based on European Space Agency land cover data time series.	209
Figure 8.5:	Areas designated for extractive activities in the Andean region (South America).	210
Figure 8.6:	Global area allocation for food production.	210
Figure 8.7:	Agricultural area 2000-2014.	211
Figure 8.8:	Food supply in the world (kcal/capita per day).	211
Figure 8.9:	Soybean production in South America, 2000-2014.	211
Figure 8.10:	Production of oil palm fruit in South-East Asia.	211
Figure 8.11:	Numbers of herbivores and poultry.	212
Figure 8.12:	Numbers of pigs, 2000-2014.	212
Figure 8.13:	Permanent meadows and pastures (1,000 ha).	212
Figure 8.14:	Forest land in the world, 2000-2015.	212
Figure 8.15:	Forest area annual net change, (1990-2000, 2000-2010, 2010-2015).	213
Figure 8.16:	Natural forest area by region, 1990-2015.	214
Figure 8.17:	Coastal erosion rates at selected sites in the Arctic.	216
Figure 8.18:	Estimated coastal erosion threat in the Arctic.	217
Figure 8.19:	Potential impacts of climate change on food security.	218
Figure 8.20:	Make-up of total food waste in developed and developing countries.	219
Figure 8.21:	Share of global production volumes traded internationally in 2014.	219
Figure 8.22:	Developing countries: net cereals trade (million tons).	219
Figure 8.23:	Global forest ownership, 2002-2013 (%).	221
Figure 8.24:	Global maps of land deals, number of land deals per country (top), land deal area per country (bottom).	222
Figure 8.25:	Benefits of tenure-secure lands outweigh the costs in three Latin American countries.	223
Figure 8.26:	Distribution of agricultural land holdings: females.	225
Figure 8.27:	Fertilizer and maize prices, 2000-2010.	226
Figure 8.28:	Where should subsidies fit?	226
Figure 8.29:	The provision of ecosystem services from natural capital: linkages between ecosystem services and human well-being.	227

Freshwater

Figure 9.1:	Global hydrological fluxes and storages (expressed in 1,000 km ³ per year), illustrating natural and anthropogenic cycles.	238
Figure 9.2:	Shrinkage of Lake Chad.	239
Figure 9.3:	United States water withdrawals from all sources (1950-2010).	241
Figure 9.4:	Global hydrogeological map illustrating various aquifers and groundwater resources.	241
Figure 9.5:	Global trends in increasing groundwater use.	242
Figure 9.6:	Examples of surface streams affected by acid and metalliferous drainage (AMD) and/or tailings discharges: (left) Urban stream severely affect by AMD in western Witwatersrand Basin, Johannesburg, South Africa; (right) Tailings sediment from Samarco Dam.	243
Figure 9.7:	Rivers originating in the Hindu-Kush Himalayas are among the most meltwater-dependent systems.	243
Figure 9.8:	Retreat of Quelccaya ice cap in Peru between 1988 (left) and 2010 (right).	244
Figure 9.9:	Global physical and economic water scarcity.	245
Figure 9.10:	Model estimates of trends in faecal coliform bacteria levels in rivers during 1990-1992 and 2008-2010.	246
Figure 9.11:	Sources of anthropogenic total phosphorus loadings to lakes (five largest lakes by surface area in each of the five UN Environment regions), showing average percentage contributions in 2008-2010 annual loads.	247
Figure 9.12:	Model estimates of trends in biochemical oxygen demand (BOD) concentrations in rivers between 1990-1992 and 2008-2010.	248
Figure 9.13:	Source and pathways of pharmaceutical and personal care products (PPCPs) entering surface and groundwater, highlighting need for improved detection of commonly found PPCPs and their transformative products.	249
Figure 9.14:	Status and trends of the world's wetlands disaggregated by region.	250
Figure 9.15:	Taxonomic differences in threat frequency for 449 declining freshwater populations in Living Planet Index (LPI) database.	251
Figure 9.16:	Migratory fish from the Living Planet Index (LPI) exhibiting a decline of 41 per cent between 1970 and 2012, with a recent upturn, and freshwater LPI for 881 monitored freshwater species exhibiting an 81 per cent decline.	252
Figure 9.17:	Variations in trends in drinking water supply coverage across regions.	252

Figure 9.18:	Summary of global progress in providing basic drinking water services and disproportionate impact on women in areas still lacking access to basic drinking water services.....	253
Figure 9.19:	Proportion of population using improved sanitation facilities in 2015.....	254
Figure 9.20:	Location of dams and reservoirs around the world. Data include dams associated with reservoirs that have a storage capacity of more than 0.1 km ³ and may not represent large dams and reservoirs that have been constructed in more recent years.....	255
Figure 9.21:	Morbidity (total disability-adjusted life years, DALYs) from diarrheal diseases (all ages) for females (upper graphic) and males (lower graphic), globally.....	256
Figure 9.22:	Hermanus Conjunctive Use.....	261
Figure 9.23:	Supply of and demand for water, Greater Hermanus, 1971-2001 and 2002-2017.....	262
Figure 9.24:	Ramsar sites designated by year and by region.....	263
Approach to Assessment of Policy Effectiveness		
Figure 10.1:	Methodological approach for assessing policy effectiveness: top-down and bottom-up approach.....	277
Figure 10.2:	Approach of assessing policy effectiveness from the bottom-up	279
Policy Theory and Practice		
Figure 11.1:	Conceptual outline of policy effectiveness analysis.....	285
Figure 11.2:	The policy cycle.....	286
Figure 11.3:	Results of expert perspectives on European energy efficiency policies.....	288
Air Policy		
Figure 12.1:	Regional allocation of cumulative CO ₂ emissions.....	306
Figure 12.2:	Population-weighted annual country-wide mean concentration of PM _{2.5} in 2016.....	316
Figure 12.3:	Ozone-depleting substance consumption in ozone depletion tons in 2016.....	317
Figure 12.4:	National total GHG emissions in 2014 in MtCO ₂ e, including land-use change and forestry sources and sinks.....	318
Biodiversity Policy		
Figure 13.1:	Cumulative number of countries that have adopted the NBSAPs as of 2018.....	325
Figure 13.2:	Inshore fishing is an important source of food in Fiji, and many of these inshore areas are under traditional tenure by local communities.....	327
Figure 13.3:	National Environmental Security Taskforces are direct liaisons between national bureaucracies and the INTERPOL National Central Bureau; image showing seizure of 114kg of tiger bones.....	329
Figure 13.4:	Usage of the terms containing 'biodiversity', 'eco' and 'ecosystem services' over time in Australian Government environment portfolio media releases (n= 3,553). Error bars indicate 95 per cent confidence intervals based on the ecosystem services framing subsample (n = 516).....	333
Figure 13.5:	The SGSV is located 100m inside a mountain on a remote island in the Svalbard archipelago, midway between mainland Norway and the North Pole, and the samples are stored at -18°C.....	334
Figure 13.6:	The City of Edmonton: the River Valley park system along the North Saskatchewan River as seen from downtown Edmonton.....	336
Figure 13.7:	Trends in national legislation relevant to the prevention or control of invasive alien species (IAS) for 196 countries reporting to the Convention on Biological Diversity (1967–2016), showing specifically the percentage of countries having a combination of: (i) IAS legislation; (ii) NBSAP targets on IAS; and (iii) IAS targets aligned with Aichi Target 9.....	339
Figure 13.8:	Percentage of countries whose institutions have a clear mandate and/or legal authority to manage IAS (a positive result is given by a Yes and is included in the overall percentage).....	339
Figure 13.9:	The Red List Index (RLI) for 1980–2017 for mammals, birds and amphibians, showing the trends driven only by utilization (by only including utilized species).....	340
Figure 13.10:	The world Ecological Footprint by component (land type) between 1961 and 2013, measured by number of Earths.....	342
Oceans and Coastal Policy		
Figure 14.1:	Coverage of Marine Protected Areas.....	362
Figure 14.2:	Areas of predicted deep-sea vulnerable marine ecosystems.....	365
Figure 14.3:	Bottom-trawling and closed VMEs from 2006 to 2016.....	365
Land and Soil Policy		
Figure 15.1:	Linkage between the land-related SDG target 15.3 and other SDGs.....	376
Figure 15.2:	The extent of the Great Green Wall in northern China.....	381
Figure 15.3:	Trends in land degradation and restoration worldwide.....	390
Figure 15.4:	Terrestrial protected area as a percentage of total land area per country (1990-2014).....	391
Figure 15.5:	Ratio of land consumption rate to population growth rate by region and period (1990-2015).....	392
Freshwater Policy		
Figure 16.1:	Map showing location and status of all United States of America and Canadian Great Lakes Areas of Concern.....	404
Figure 16.2:	Change in global population by drinking water source, 1990-2015 (billions).....	415
Figure 16.3:	Regional trends in proportion of national population practising open defecation, 2000-2015.....	415

Figure 16.4:	Progress towards universal basic sanitation services (2000-2015) among countries where at least 5 per cent of the population did not have basic services in 2015.	416
Figure 16.5:	Trends in global water withdrawal by sector between 1900 and 2010 (km ³ per year).	417
Figure 16.6:	Proportion of total water withdrawn for agriculture.	417
Figure 16.7:	Changes in global gross crop water demand over time.	418
Systemic Policy Approaches for Cross-cutting Issues		
Figure 17.1:	Climate finance on adaptation.	430
Figure 17.2:	Health and sustainability of country X's dietary intake.	436
Figure 17.3:	An illustrative energy system.	437
Figure 17.4:	Building a circular economy.	440
Figure 17.5:	Closed-loop material flow diagram of 6R elements and the four life cycle stages.	441
Figure 17.6:	Outline of a circular economy.	443
Figure 17.7:	Domestic extraction and domestic material consumption.	445
Figure 17.8:	Citizen engagement in sharing: the percentage of 2013 survey respondents who had engaged in a sharing scheme, either formal or informal in the previous 12 months.	446
Outlooks in GEO-6		
Figure 19.1:	Conceptual framing of the chapters in Part C of GEO-6, how they are related, and how they contribute to a holistic analysis and assessment of human-Earth systems that identifies transformative development pathways	468
A Long-Term Vision for 2050		
Figure 20.1:	A framework for the classification and grouping of the SDGs.	474
Future Developments Without Targeted Policies		
Figure 21.1:	Selected targets and their related clusters as examined in this chapter.	490
Figure 21.2:	Future projections of the global population (left) and urbanization (right).	491
Figure 21.3:	Future projections of total GDP per region under SSP2 (left) and global GDP under SSP2 and SSP3 (right).	491
Figure 21.4:	Future projections of global average crop yield (top left), crop production (top right), agricultural area (bottom left), and forest and other natural land area (bottom right).	493
Figure 21.5:	Future projections of global undernourished population.	494
Figure 21.6:	Future projections of relative local species richness for a range of climate stabilisation scenarios and Mean Species Abundance (MSA) for SSP2 and SSP3 land-use.	494
Figure 21.7:	Future projections of global primary energy consumption (left panel) and per energy carrier in the SSP2 marker scenario (right panel).	495
Figure 21.8:	Projected increase in global CO ₂ emissions (left) and total GHG emissions (right).	496
Figure 21.9:	Global mean temperature increase.	497
Figure 21.10:	Future projections of emissions for air pollutants SO ₂ , NO _x and BC.	498
Figure 21.11:	Projected under-five mortality rate in 2030.	502
Pathways Toward Sustainable Development		
Figure 22.1:	The scenarios from the Roads from Rio+20 study.	514
Figure 22.2:	Selected measures and their related clusters as examined in this chapter.	515
Figure 22.3:	Percentage change in non-energy crop production versus the percentage change in non-energy cropland area from 2010 to 2030 and 2050.	517
Figure 22.4:	Global CO ₂ emissions and associated global mean temperature increase for the SSP2 baseline and derived scenarios consistent with the Paris target to stay well below 2°C increase.	521
Figure 22.5:	2010-2050 energy intensity improvement rate and the 2050 share of low-greenhouse gas technologies in total energy mix of the scenarios included in the SSP database.	522
Figure 22.6:	Different pathways leading to a global mean temperature increase well below 2°C.	523
Figure 22.7a:	Projected global emissions for SO ₂ , NO _x and black carbon under different climate and air pollution policies.	525
Figure 22.7b:	Differences in air pollution emissions between various climate mitigation scenarios, and the SSP2 baseline.	525
Figure 22.8:	Percentage of the population exposed to particulate matter of less than 2.5 µm in diameter (PM _{2.5}) concentrations under the WHO guideline and interim target for 2050.	527
Figure 22.9:	Quick-scan of synergies and trade-offs between selected measures and targets.	534
Figure 22.10:	Global mean temperature increase in 2100 versus bioenergy use in various SSP scenarios	536
Bottom-up Initiatives and Participatory Approaches for Outlooks		
Figure 23.1:	Outline of how this chapter's bottom-up approaches complement the top-down findings of Chapters 21 and 22 and how together they can offer policy insights for Chapter 24.	551
Figure 23.2:	The number of initiatives covered in a sample of platforms that feature bottom-up sustainability initiatives (see Annex 23-1 for a brief description of the platforms).	555
Figure 23.3:	The SDGs represented proportionally by how they are covered by the selected bottom-up sustainability initiative platforms. Some initiatives are narrower in scope and strictly relate to one, two or three SDGs, while others are diverse and capture a wider range of SDGs (four or more) (see Annex 23-1 for a brief description of the initiative platforms).	555
Figure 23.4:	SDGs targeted by the total workshop seeds and the total Climate CoLab proposals.	556
Figure 23.5:	Actor types represented by total seeds and total Climate CoLab proposals.	557

Figure 23.6a: Regions covered by Climate CoLab proposals.	557
Figure 23.6b: Regional breakdown of Climate CoLab proposals.	557
Figure 23.7: How each theory of change is represented by the total seeds and proposals.	558
Figure 23.8: Heat map of workshop seeds, showing pairings of specific measures/interventions and SDGs.	561
Figure 23.9: Heat map of Climate CoLab proposals showing pairings of measures/interventions and SDGs.	562
Figure 23.10: Inter-cluster pairings across the seeds and Climate CoLab proposals.	563
Figure 23.11: Total number of workshop seeds and Climate CoLab proposals addressing each intervention in the agriculture, food, land and biodiversity cluster (seeds and proposals are double counted when they meet multiple measures).	564
Figure 23.12: Total number of workshop seeds and Climate CoLab proposals addressing each intervention in the energy, climate and air cluster (seeds and proposals are double counted when they meet multiple measures).	565
Figure 23.13: Total number of workshop seeds and Climate CoLab proposals addressing each intervention in the combined clusters for freshwater and oceans (seeds and proposals are double counted when they meet multiple measures).	565
Figure 23.14: Total number of workshop seeds and Climate CoLab proposals addressing each intervention in the human well-being cluster (seeds and proposals are double counted when they meet multiple measures)	566
Figure 23.15: The interventions highlighted by the outlook chapters of the GEO Regional Assessments.	567
Figure 23.16: Number of regions emphasizing interventions within the clusters identified in Chapter 22.	569
Figure 23.17: Seeds and proposals by cluster.	570
Figure 23.18: Count of the number of pairings of "other" measures with at least one intervention from a main cluster group.	571
Figure 23.19: Conceptual framework for mutually beneficial feedbacks between top-down and bottom-up approaches to generating sustainable scenarios.	575
 The Way Forward	
Figure 24.1: Different policy approaches.	583
 Future Data and Knowledge Needs	
Figure 25.1: Some of the benefits of citizen science.	599
Figure 25.2: Levels of citizen science by increasing depth of the participation.	600
Figure 25.3: An example of citizen science that demonstrates how it is needed and can be replicated.	601
Figure 25.4: GLOBE Students in St. Scholastica Catholic School in Nairobi collecting and recording the amount of precipitation for the GPM Satellite Mission field campaign.	602
Figure 25.5: Citizen scientists collecting environmental data.	603
Figure 25.6: The PPSR-Core data-model framework.	604
Figure 25.7: Characteristics of big data and the role of analytics.	605
Figure 25.8: Forecasting air quality for Indian districts.	607
Figure 25.9: Comparing indigenous/traditional knowledge and Western science.	609
Figure 25.10: Recognition of indigenous peoples in the 2030 Agenda for Sustainable Development.	611
Figure 25.11: Lands/territories of indigenous peoples are the base of their knowledge.	611
Figure 25.12: Indigenous peoples as stewards of the environment.	612
Figure 25.13: The evolution of the data landscape.	614
 Annexes	
Figure A.1: Theory of Change of GEO-6.	623
Figure A.2: The four-box model for the qualitative communication of confidence.	625
Figure A.3: Likelihood scale for the quantitative communication of the probability of an outcome occurring.	626
Figure A.4: Relative progress on SDG indicators.	630
Figure A.5: Environmental Dimensions of the SDGs – Score Card.	631

Tables

Drivers of Environmental Change

Table 2.1:	Interrelationships between the drivers.	49
------------	---	----

Air

Table 5.1:	Some atmospheric chemical components.	109
Table 5.2:	Global environmental agreements relevant to climate change, stratospheric O ₃ depletion and PBTs	132
Table 5.3:	WHO Air Quality Guidelines and Interim Targets.	132

Oceans and Coasts

Table 7.1:	Estimates of economic value, employment and major environmental impacts of the major ocean-related industries.	180
Table 7.2:	Global capture fisheries employment.	192

Approach to Assessment of Policy Effectiveness

Table 10.1:	Policy typology.	276
-------------	------------------	-----

Policy Theory and Practice

Table 11.1:	Typical stages of regulatory impact assessment	290
-------------	--	-----

Air Policy

Table 12.1:	Typology of policy and governance approaches described in this chapter.	303
Table 12.2:	Summary of assessment criteria: United Kingdom of Great Britain and Northern Ireland's energy and climate policies.	305
Table 12.3:	Summary of assessment criteria: Excess diesel emissions in Europe.	308
Table 12.4:	Summary of assessment criteria: Improved cookstoves in Kenya.	310
Table 12.5:	Summary of assessment criteria: AirNow, real-time air quality data and forecasts.	312
Table 12.6:	Summary of assessment criteria: ASEAN Agreement on Transboundary Haze Pollution.	314

Biodiversity Policy

Table 13.1:	Typology of policy and governance approaches described in this chapter.	326
Table 13.2:	Summary of assessment criteria: Locally Managed Marine Areas in Fiji case study.	328
Table 13.3:	Summary of assessment criteria: Project Predator case study.	330
Table 13.4:	Summary of assessment criteria: Working for Water case study.	332
Table 13.5:	Summary of assessment criteria: Svalbard Global Seed Vault case study.	335
Table 13.6:	Summary of assessment criteria: Edmonton Natural Area Systems Policy.	337
Table 13.7:	Policy-sensitive indicators.	338

Oceans and Coastal Policy

Table 14.1:	Example of governance approaches and policy instruments to address coral bleaching, marine litter and overfishing.	351
Table 14.2:	Australia's Great Barrier Reef	352
Table 14.3:	Regional Plan on Marine Litter Management in the Mediterranean.	354
Table 14.4:	Chilean fisheries.	356
Table 14.5:	British Columbia fisheries.	359
Table 14.6:	International cooperation resolutions.	361

Land and Soil Policy

Table 15.1:	Recent milestones in land governance and sustainable development.	377
Table 15.2:	Typology of policy and governance approaches described in this chapter.	378
Table 15.3:	Summary of the assessment criteria for foreign investments.	379
Table 15.4:	Summary of the assessment criteria for desertification and dust control in China.	381
Table 15.5:	Summary of the assessment criteria for land decontamination in Viet Nam.	384
Table 15.6:	Summary of the assessment criteria for NT implementation in Australia.	386
Table 15.7:	Summary of the assessment criteria on Milan Urban Food Policy Pact and its impacts in Mexico.	388
Table 15.8:	Indicators for assessing land policy effectiveness and for measuring the progress towards the achievement of global environmental goals.	389

Freshwater Policy

Table 16.1:	Policy approaches and case studies.	401
Table 16.2:	Evaluation of the effectiveness of the Great Lakes Water Quality Agreement.	403
Table 16.3:	Evaluation of the effectiveness of adaptive management of the Glen Canyon Dam.	406
Table 16.4:	Evaluation of the effectiveness of the flood risk management policy in England.	408
Table 16.5:	Three options for free basic water supply.	410
Table 16.6:	Evaluation of the effectiveness of economic incentives through the Free Basic Water Policy in South Africa.	411
Table 16.7:	Evaluation of the effectiveness of the Australian mining industry's Water Accounting Framework.	413
Table 16.8:	The JMP Service Ladder for drinking water.	414

Systemic Policy Approaches for Cross-cutting Issues

Table 17.1:	Agricultural system components, production, food loss and waste, consumption	435
Table 17.2:	Recommended intake for a healthy and sustainable diet.	436
Table 17.3:	Examples of policy focus to achieve key elements of the circular economy	442

A Long-Term Vision for 2050

Table 20.1:	Selected targets and indicators for human well-being.....	477
Table 20.2:	Selected targets and indicators for the natural resource base.....	479
Table 20.3:	Selected targets and indicators for sustainable production and consumption.....	480

Future Developments Without Targeted Policies

Table 21.1:	Percentage of countries by region projected to achieve selected SDG targets in 2030.....	503
Table 21.2:	Past and future trends related to selected targets (see Section 20.4).	504
Table 21.3:	Historic and business-as-usual trends in resource use efficiency.....	505

Pathways Toward Sustainable development

Table 22.1:	Trends in resource-use efficiency: business as usual (Chapter 21) versus pathways towards achieving the targets (this chapter).	532
Table 22.2:	Measures with significant synergies or trade-offs across the selected targets.	533

Bottom-up Initiatives and Participatory Approaches for Outlooks

Table 23.1:	Different types of assessment model.....	551
Table 23.2:	Coding dimensions.....	553
Table 23.3:	Summary of enabling and disruptive conditions for the appropriate scaling up, out and deep of potentially transformative innovations.	573

Future Data and Knowledge Needs

Table 25.1:	A selection of citizen-science projects and websites.....	602
Table 25.2:	Pulse Lab research and studies.	605
Table 25.3:	Example public-private partnerships.....	609
Table 25.4:	Studies that combine traditional knowledge with Western scientific knowledge.....	610
Table 25.5:	Studies on the potential of traditional knowledge for sustainable development.	611

Annexes

Table A.1:	Examples of Global Environmental Assessments and their links to GEO-6	621
Table A.2:	Sources of low confidence.....	628
Table A.3:	Description of environment relevant SDG targets and indicators in the SDG Global Indicator Framework	632
Table A.4:	List of International Environmental Agreements signed between 2010 and 2015	641

Boxes

Introduction and Context

Box 1.1: Concept of Well-being..	08
Box 1.2: Multidimensional aspects of the analysis.	14

Drivers of Environmental Change

Box 2.1: Relationship between higher population and growth rate of consumption and resource use.	25
Box 2.2: The demographic dividend.	25
Box 2.3: Electronic waste.	41
Box 2.4: Precision agricultural technologies.	42
Box 2.5: IPAT identity.	51

The Current State of our Data and Knowledge

Box 3.1: Statement from Ban Ki Moon, 2015.	59
Box 3.2: Gender statistics.	64
Box 3.3: Gender-informed questions..	65
Box 3.4: Statement from the United Nations Secretary-General.	69
Box 3.5: Article 76 of the 2030 Agenda..	70

Air

Box 5.1: UNEA 3/8 Resolution.	132
------------------------------------	-----

Biodiversity

Box 6.1: Biodiversity, disease and One Health.	145
Box 6.2: The threats to biodiversity from marine litter and microplastics.	151
Box 6.3: Extreme events – further pressures on biodiversity.	152
Box 6.4: International Union for the Conservation of Nature (IUCN)..	155
Box 6.5: Agrobiodiversity and gender.	161
Box 6.6: Importance of traditional practices and knowledge in pollinator conservation..	161
Box 6.7: Climate change and the need for ecosystem-based adaptation: the Hindu Kush Himalayas.	163
Box 6.8: The international wildlife trade and CITES.	165
Box 6.9: Biodiversity conservation and poverty..	166
Box 6.10: Female rangers in South Africa.	166

Oceans and Coasts

Box 7.1: Fisheries in the polar oceans.	184
Box 7.2: Mercury in the marine environment..	184
Box 7.3: Coastal sand mining..	189
Box 7.4: Deep sea mining.	190
Box 7.5: Anthropogenic ocean noise..	190
Box 7.6: Examples of existing global policy commitments to sustainable fisheries using an ecosystem approach (dates of agreements in brackets)..	192

Land and Soil

Box 8.1: Livelihood impacts in the Arctic.	216
Box 8.2: The Syrian crisis: droughts and land degradation as factors.	218
Box 8.3: Cultural values and conservation in Bhutan..	223

Freshwater

Box 9.1: Impacts of climate change on disappearing lakes and wetlands.	239
Box 9.2: Water quality impacts of mining..	243
Box 9.3: Jordan faces a combined refugee and water crisis.	257
Box 9.4: How cities face water scarcity.	259
Box 9.5: Hermanus, near Cape Town, Western Cape Province, South Africa: A case study for conjunctive surface- and groundwater development and management..	261

Policy Theory and Practice

Box 11.1: Carbon valuation as part of United Kingdom of Great Britain and Northern Ireland's policy assessment.	291
--	-----

Biodiversity Policy

Box 13.1: Global recognition of the link between human health and biodiversity.	325
Box 13.2: Highlights of the gender and equity dimensions in biodiversity policies.	326
Box 13.3: The centrality of indigenous peoples and local communities.	331

Land and Soil Policy	
Box 15.1: The Concepts of Land and Soil.....	376
Box 15.2: UNCCD Statement on food system.....	387
Systemic Policy Approaches for Cross-cutting Issues	
Box 17.1: Case study: 'Living With Floods' programme in Viet Nam.....	431
Box 17.2: Case study: Food losses and waste – multiple policy approaches in Japan.	434
Box 17.3: Case study: Support for renewables in Germany: feed-in tariffs.	438
Box 17.4: Case study: Demand-side management in India: affordable LED lights for all.	439
Box 17.5: Sustainable materials management.	441
Box 17.6: Case study: Ellen MacArthur Foundation – A toolkit for policymakers in delivering the circular economy.....	443
Future Developments Without Targeted Policies	
Box 21.1: Waste as an important cause of environmental degradation.....	488
Box 21.2: The Shared Socioeconomic Pathways.	489
Box 21.3: The need for coordination among environmental assessments.....	489
Box 21.4: Climate change impacts on agriculture.	492
Box 21.5: Country level achievement of selected SDG targets.....	503
Pathways Toward Sustainable Development	
Box 22.1: Roads from Rio+20.....	515
Box 22.2: Contribution of land-use-based mitigation options to climate policies.	523
Box 22.3: The Climate and Clean Air Coalition.	525
Box 22.4: Possible synergy between climate mitigation and reducing air pollution in China.....	526
Box 22.5: A snapshot of interrelations between the selected measures and targets.	533
Bottom-up Initiatives and Participatory Approaches for Outlooks	
Box 23.1: IPBES and bottom-up scenario processes.....	549
Box 23.2: Climate CoLab.....	552
Box 23.3: The Global Climate Action portal.....	554
Box 23.4: Climate CoLab Winners.....	559
Box 23.5: Urban systems.....	560
Box 23.6: Case study: food systems.....	572
The Way Forward	
Box 24.1: The health benefits outweigh the costs of implementing the Paris Agreement.....	588
Future Data and Knowledge Needs	
Box 25.1: Examples of open-data systems.....	606
Box 25.2: Examples of web-based and geospatial technologies using big data.	606
Box 25.3: Comprehensive air-quality forecasting in India using big data.....	607
Box 25.4: Some challenges of using Big Data.....	608
Box 25.5: Complimentary uses of traditional knowledge and Western science.....	610





Foreword

The sixth *Global Environment Outlook* is an essential check-up for our planet. Like any good medical examination, there is a clear prognosis of what will happen if we continue with business as usual and a set of recommended actions to put things right. *GEO-6* provides both a statement of the problems and a how-to guide to advance us on the path set out in the 2030 Agenda and the 17 Sustainable Development Goals.

The theme, “Healthy Planet, Healthy People”, highlights the inextricable link between the environment and our survival and progress. The challenges outlined are multiple. From climate change to the extinction of species, economies too dependent on the wasteful use of resources and unprecedented pressure on terrestrial and marine ecosystems, we are at a decisive moment in our role as custodians of the planet.

It is not all bad news. Many indicators point to progress on issues such as global hunger, access to clean water, sanitation and clean energy. We can also see some signs of the decoupling of environmental degradation and unsustainable resource use from economic growth, as well as unprecedented technological innovation.

The overall message, however, is that we need a significant shift in trajectory – indeed, the kind of transformational change prescribed by the Intergovernmental Panel on Climate Change in its recent report on limiting global warming to 1.5 degrees.

GEO-6 details both the perils of delaying action and the opportunities that exist to make sustainable development a reality. We have the necessary policy guidance and the science that underpins it. The only missing ingredient for success is our collective resolve.



A handwritten signature of António Guterres in black ink. The signature is fluid and cursive, with a long horizontal stroke at the end.

António Guterres
Secretary-General of the United Nations

January 2019

Foreword

"Grow now, clean up later". That's sadly been the business model for much of the world since the industrial revolution. It's as if looking after environment is a needless distraction, but ultimately a nice add-on when economies are doing well, and when luxuries can be afforded.

The *Global Environment Outlook*, now in its sixth edition, has been a key driver of the shift in this mindset. Grounded in the best available science and real-world case studies, it underscores the fact that a healthy planet is a prerequisite for healthy people, and that is in turn the foundation of any healthy economy. And most importantly, it shows how it's possible to win on all fronts.

In this drive towards a green economy, greater sustainability and the hope that we can thrive rather than merely survive, there has never been a more critical moment than now. The science and data are crystal clear on the multitude of challenges we face, but also the small window of opportunity we have to turn things around.

The *Global Environment Outlook* is therefore a roadmap to achieving the United Nations' Agenda 2030, in which hunger and poverty are consigned to history, and where biodiversity, oceans, land and freshwater are protected and restored to health.

It makes it clear that achieving this requires a transformation in human lifestyles and productive activities: our industry, agriculture, buildings, transport and the energy system which powers them.

It means renewables like wind and solar must be the new norm, as must energy efficient, green buildings and transport. At the same time, this work also opens up huge economic opportunities – a new, better industrial revolution.

The task may be enormous, but we should also be inspired. Global environmental actions like the Montreal Protocol, our innovative defence against the hole in the Ozone layer, prove that we have the institutions and capacity to come together. The issue of plastics pollution has shown how diverse communities around the world – school children in Bali, coastal residents in Mumbai or surfers from Cornwall – can come together. After all, making the world a better place and cleaning up our act is a non-partisan, unifying cause we can all get behind.



A handwritten signature in blue ink, appearing to read 'Joyce Msuya', with a stylized flourish at the end.

Joyce Msuya
Acting Executive Director, UN Environment

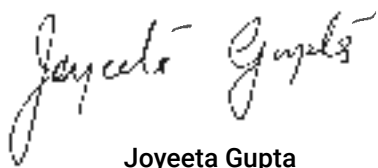
Co-Chairs' Foreword

What is the Outlook for humanity? This sixth *Global Environment Outlook (GEO-6)* shows clearly that our species now stands at a crossroads. It can choose a challenging but navigable path towards a new golden age of sustainable development as envisaged by the United Nations' Agenda 2030 in which human hunger and poverty are consigned to history through the sustainable use of Earth's resources and the natural environment that leaves no-one behind. Or it can continue with current trends and practices, which will lead to a losing struggle against environmental disruptions, which threaten to overwhelm large parts of the world.

GEO-6 clearly identifies the problems that have to be addressed if this latter outcome is to be avoided. But it also points to the solutions to these problems, to ways in which the aspirations of the Sustainable Development Goals (SDGs) can be realised and Earth's air, biodiversity, oceans, land and freshwater restored to health, to the incalculable benefit of Earth's people: Healthy Planet, Healthy People, the title of *GEO-6*.

GEO-6 makes clear that achieving the SDGs will require a transformation in human lifestyles and productive activities: our industry, agriculture, buildings, transport and the energy system which powers them. This necessary transformation over the coming decades represents an enormous economic opportunity to those countries, policy makers and businesses who show the enterprise and innovative spirit to put in place the technologies, social practices and institutions that can make sustainable development a reality.

As co-chairs of the sixth *Global Environment Outlook* we have overseen the work of the tireless authors and experts who have contributed to this analysis. The scientific integrity of the process has been monitored by the Scientific Advisory Panel. The High Level Group helped us to find the language that can communicate to policymakers. The Secretariat provided the staying power to ensure that the entire process moved smoothly. Some States provided the necessary funding, encouraged us and hosted some of our meetings. We feel that the *GEO-6* has gathered the evidence to show what needs to be done, and what can be done. We respectfully present it to the world's decision makers, and ask them to face and address these challenges, for all of our sakes and future generations.



Joyeeta Gupta



Paul Ekins

Co-Chairs' Message

UN Environment's sixth *Global Environmental Outlook (GEO-6)* has reviewed the state of the health of the environment and the related health of the people, and the prospects for meeting the Sustainable Development Goals (SDGs) of the UN's Agenda 2030. As co-chairs, we draw six key messages from the report:

First, a healthy planet supports healthy people: A healthy planet is important for the health and well-being of all people. It directly supports the lives and livelihoods of 70 per cent of the Earth's population living in poverty [SPM 2.2.2; 6, 6.3.4, 6.6.3; boxes 6.5, 13.2], in particular those who are very poor, and it provides the basis for the production of the goods and services that are necessary for the global formal economy, which had a global GDP value of \$US 75 trillion in 2017. Overall the biosphere is essential for human survival and civilization and its value to humans is therefore effectively infinite. However, for some purposes it is useful to calculate the monetary value of ecosystem goods and services; as an example the total global ecosystem services have been valued at \$US (2007) 125 trillion/year [1.3.1]. This number does not capture the benefits of, for example, a climate suitable for agriculture or how melting glaciers affect the water security of more than a billion people [4.2.2], and so is clearly an underestimate. The value of lost ecosystem services between 1995 and 2011 have been estimated at \$US 4-20 trillion (Costanza *et al.* 2014). More particularly, the value of pollinators which provide crucial services for commercial and non-commercial food production, has been estimated at \$US 351 Billion/year to the commercial sector (Lautenbach *et al.* 2012).

Second, an unhealthy planet leads to unhealthy people: The planet is becoming increasingly unhealthy through the negative impacts of biodiversity loss (including pollinators, coral reefs and mangroves), climate change and other air pollution, water pollution, ocean pollution and depletion, and land use change. An unhealthy planet has huge social costs in terms of human health and well-being as well as on the formal economy and livelihoods worldwide. As with ecosystem goods and services, these costs are difficult to express comprehensively in monetary or other terms. However, *GEO-6* provides data that illustrate the sort of costs involved. For example, exposure to indoor/outdoor air and water pollution costs at least 9 million lives annually [4.1.1] including 300,000 in the G7 countries in 2015 (Organisation for Economic Co-operation and Development [OECD] 2017). About 2.8 million people died in 2015 from indoor air pollution [5.3.1] and about 2.8 million depend on unclean traditional biomass [21.2.3]. Many more millions suffer from ill-health and loss of livelihoods. Pollution-related costs have been estimated at \$US 4.6 trillion annually [1.3.1]. 29 per cent of land is degraded affecting the lives and livelihoods of 1.3-3.2 billion people [8.3.2] and slow onset disasters are triggering migration [9.3.4; 9.7.3]. In 2016, 24.2 million people were internally displaced in 118 countries as a result of sudden-onset disasters [4.1.2]. Such disasters affected not just the poor countries, but also rich countries like the USA and Japan. Between 1995-2015, 700,000 people died and 1.7 billion people were affected by extreme



weather events costing \$US 1.4 trillion [4.1.2; Figure 4.2] (Centre for Research on the Epidemiology of Disasters and United Nations Office for Disaster Risk Reduction 2015). Between 2010 and 2016, an average of around 700 extreme events each year cost an average of \$US 127 billion per annum. While 90 per cent of the losses came from high and upper-middle income countries, the less than 1 per cent of the losses from low-income countries amounted to around 1.5 per cent of their GDP, a much higher proportion than in high-income countries, and was almost all uninsured (Watts *et al.* 2017). The damage of climate variability and change to some small island regions is in the order of 1-8 per cent of GDP averaged over 1970-2010 (United Nations Environment Programme [UNEP] 2016a); if average global warming is not limited to 1.5°C, small island states and coastal populations may face existential threats. Water-related health costs are estimated at about \$US140 billion in lost earnings and \$US 56 billion in health costs annually (LiXil, Water Aid and Oxford Economics 2016). Such impacts are likely to exacerbate inequalities within and between countries, as opposed to reducing them in line with SDG10.

Third, the drivers and pressures leading to an unhealthy planet need to be addressed: The drivers and pressures result from a continuing failure to internalize environmental and health impacts into economic growth processes, technologies and city design. The pressures arise from massive use of chemicals (many with toxic health and environmental implications), huge waste streams (many largely unmanaged), committed and intensifying climate change impacts, and inequality which contributes to demographic changes and other drivers and pressures. The environmental footprint of rich people is significantly higher than that of poorer people. For example, the monthly emissions per capita in rich countries are mostly higher than the yearly emissions per capita in poorer countries (Ritchie and Roser 2018). The wealthiest countries consume 10 times the materials per person compared to the poorest countries (UNEP 2016b). While ideas around a green, healthy and inclusive economy aim to address these challenges, these ideas have yet to be systematically reflected in existing national policies. The IPCC 1.5°C report highlights

the very limited time left to reduce greenhouse gas emissions to the extent necessary to limit average global warming to this level, thereby avoiding the potentially very expensive adaptation costs that will otherwise be required (Intergovernmental Panel on Climate Change 2018).

Fourth, current science justifies policy action now, but more detailed knowledge can enable more refined and preemptive policy.

Existing knowledge is sufficient to mobilize action now [1,2, 4-9]. New knowledge including disaggregated data from earth observation, in-situ data, citizen science, ground truthing and indigenous and local knowledge are necessary in national policy and accounting more broadly [3]. There are major benefits in accounting systems that register the details about who causes damage to the environment, how and why; what is the extent of nature's contributions to humans, the loss of ecosystem goods and services; and who is affected [Figure 3.6]. Statistics and accounting systems also need to recognize the realities of the predominantly poor people in the informal economy, who are often particularly dependent on nature's contributions to people, and hence more vulnerable to environmental degradation.

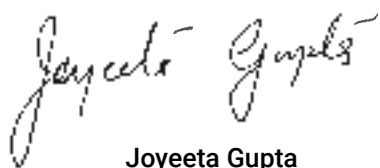
Fifth, environmental policy is necessary but inadequate by itself to address systemic ecological problems, solutions to which require a more holistic approach.

Current (inter) national policies are not on track to address the key environmental challenges effectively and equitably, in line with the aspirations of the SDGs. Environmental considerations need to be integrated into all policy areas, such that the potential and actual implications for natural resources and the environment are robustly included in policies for economic growth, technological development and urban design, so that there is effective long-term decoupling between economic growth, resource use and environmental degradation. Climate mitigation needs to be accompanied by policy for the equitable adaptation to committed climate change. Policies will only be effective if they are well designed, involving clear goals and flexible mixes of policy, including monitoring, instruments aimed at achieving them [12-17] and when access to judicial remedies are available [23.3; 23.11; 24.2]. Such a holistic approach need not require additional economic costs. If 2 per cent of global GDP is invested in maintaining and restoring natural capital, it could deliver the same economic growth outcome as a similar investment along current lines

[18.1]. The health benefits from reduced air pollution of achieving the 2°C target could be 1.4-2.5 times the cost of mitigation, the higher figure involving benefits of \$US 54.1 trillion for a global expenditure of \$US 22.1 trillion. Moving from a 2°C to a 1.5°C target would generate further substantial health benefits for China and India [Box 24.1]. Food security could be enhanced if food wastage, currently running at 33 per cent globally, is curtailed [SPM 2.2.4].

Sixth, healthy people, a healthy planet and a healthy economy can be mutually supportive:

Healthy diets (less meat) and lifestyles, healthy cities with good waste management (2 out of five people lack access to waste disposal services [SPM 2.2.6; 4.4.1]) and the use of green infrastructure in built-up areas, and healthy mobility can increase labour productivity, reduce the need for land for agriculture (e.g. meat production currently uses 77 per cent of agricultural land [SPM 2.2.4; 8.5.1, 8.5.3]) and reduce the costs associated with urban congestion and transport-related pollution and address the potential trade-offs between land for food/biofuel and biodiversity protection (OECD 2017). Technological and social innovation that supports environmentally sound economic development provides a viable and attractive alternative to the 'grow now, clean up later' practices of the past. In addition, a healthy people approach requires implementation of the rights of access to clean water and food, tenure rights, and gender equality. Millions of lives could be saved and livelihoods improved by access to clean air, water, fuel and food. Secure tenure rights for poor and indigenous people would enhance their ability to protect biodiversity and the different ecosystems that sustain them – for example, indigenous and poor people live on 22 per cent of the land that supports 80 per cent of global biodiversity (Sobrevila 2008) generating billions of dollars' worth of carbon sequestration, reduced pollution, clean water, erosion control, etc. (SPM 2.2.4; 8.5.3). If gender equality is promoted, including the right to inherit and own land, then food security and many health issues relating especially to women and children could be better addressed [4.1.12]. Embracing the urgent and transformative changes that are required to accelerate the transition to a more equitable and environmentally sustainable economy, and a healthier society, through top down policy guidance and bottom-up initiatives will underpin the well-being and prosperity of countries and their people now and in the future.



Joyeeta Gupta



Paul Ekins

References

- Centre for Research on the Epidemiology of Disasters and United Nations Office for Disaster Risk Reduction (2015). *The Human Cost of Weather-Related Disasters 1995-2015*. https://www.unisdr.org/files/46796_cop21weatherdisastersreport2015.pdf.
- Costanza, R., de Groot, R., Sutton, P., van der Ploeg, S., Anderson, S.J., Kubiszewski, I. et al. (2014). Changes in the global value of ecosystem services. *Global Environmental Change* 26, 152-158. <https://doi.org/10.1016/j.gloenvcha.2014.04.002>.
- Intergovernmental Panel on Climate Change (2018). *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*. <http://www.ipcc.ch/report/sr15/>.
- Lautenbach, S., Seppelt, R., Liebscher, J. and Dormann, C.F. (2012). Spatial and temporal trends of global pollination benefit. *PLOS ONE* 7(4), e35954. <https://doi.org/10.1371/journal.pone.0035954>.
- Lixil, Water Aid and Oxford Economics (2016). *The True Cost of Poor Sanitation*. https://www.lixil.com/en/sustainability/pdf/the_true_cost_of_poor_sanitation_e.pdf.
- Organisation for Economic Co-operation and Development (2017). *Healthy People, Healthy Planet: The Role of Health Systems in Promoting Healthier Lifestyles and a Greener Future*. Paris. <https://www.oecd.org/health/health-systems/Healthy-people-healthy-planet.pdf>.
- Ritchie, H. and Roser, M. (2018). CO₂ and other greenhouse gas emissions. 23 November. Our World in Data <https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions>.
- Sobrevila, C. (2008). *The Role of Indigenous Peoples in Biodiversity Conservation: The Natural but Often Forgotten Partners*. Washington, D.C.: World Bank. <https://siteresources.worldbank.org/INTBIODIVERSITY/Resources/RoleofIndigenousPeoplesinBiodiversityConservation.pdf>.
- United Nations Environment Programme (2016a). *GEO-6 Regional Assessment for Asia and the Pacific*. Nairobi. http://wedocs.unep.org/bitstream/handle/20.500.11822/7548/GEO_Asia_Pacific_201611.pdf?isAllowed=y&sequence=1.
- United Nations Environment Programme (2016b). *Global Material Flows and Resource Productivity: Assessment Report for the UNEP International Resource Panel*. Schandl, H., Fischer-Kowalski, M., West, J., Giljum, S., Dittrich, M., Eisenmenger, N. et al. (eds.). http://wedocs.unep.org/bitstream/handle/20.500.11822/21557/global_material_flows_full_report_english.pdf?sequence=1&isAllowed=y.
- Watts, N., Amann, M., Ayeb-Karlsson, S., Belesova, K., Bouley, T., Boykoff, M. et al. (2017). The lancet countdown on health and climate change: From 25 years of inaction to a global transformation for public health. *The Lancet* 391(10120), 581-630. [https://doi.org/10.1016/S0140-6736\(17\)32464-9](https://doi.org/10.1016/S0140-6736(17)32464-9).

