

Geomorphological Hazards and Disaster Prevention

Human activities, especially in the last two centuries, have had a huge impact on the environment and landscape through industrialisation and land-use change, leading to climate change, deforestation, desertification, land degradation, and air and water pollution. These impacts are strongly linked to the occurrence of geomorphological hazards, such as floods, landslides, snow avalanches, soil erosion, and others. The work undertaken by geomorphologists includes not only the understanding but also the mapping and modelling of Earth's surface processes, and many of these processes directly affect human activities and societies. In addition, geomorphologists are now becoming increasingly involved with the dimensions of societal problem solving, which can be expressed through vulnerability analysis, along with hazard and risk assessment and management. The work of geomorphologists is therefore of prime importance for disaster prevention.

This volume, with chapters written by an international team of geomorphologists:

- provides state-of-the-art knowledge about the contribution of geomorphology to the comprehension of hazards;
- links the work undertaken by geomorphologists to the framework of the likely impacts of climatic change and global environmental change;
- shows the significance of technology (remote sensing and Geographical Information Systems) for hazard and risk assessment and management;
- demonstrates the role of geomorphology in vulnerability and risk analysis, disaster prevention and sustainability.

The language is scientifically rigorous but accessible to a wide audience of geomorphologists and other Earth scientists, including those involved in environmental science, hazard and risk assessment, management and policy.

IRASEMA ALCÁNTARA-AYALA was born in Mexico City in November, 1970. She received her first degree in Geography at the National Autonomous University of Mexico (UNAM). In 1997, she obtained her Ph.D. in Geography with speciality in Geomorphology from King's College London, University of London. Afterwards, she carried out a postdoctoral stay in the Department of Civil and Environmental Engineering at the Massachusetts Institute of Technology, Boston. She is currently Director and Professor of the Institute of Geography at the National Autonomous University of Mexico (UNAM). Her research is concentrated on mass movement processes, natural hazards, risks, vulnerability, and prevention of disasters. She has published numerous peer reviewed papers and book chapters, and has presented her work at numerous international meetings. In 2005 she was awarded the 3rd Evelyn Pruitt Lecture by the Department of Geography and Anthropology, Louisiana State University, Baton Rouge, USA. She is on the Editorial and Advisory

Editorial Boards of renowned scientific journals including *Earth Surface Processes and Landforms*, *Journal of Mountain Science*, *Singapore Journal of Tropical Geography*, among others. From 2002 to 2005, she acted as a member of the International Association of Geomorphologists (IAG) Executive Committee and was appointed as the International Geographical Union (IGU) Representative within the Earthquakes and Megacities Initiative. In 2007, she represented IGU at the conference "Global Scientific Challenges: Perspectives from Young Scientists" (an international conference celebrating 75 years of ICSU). She was IGU theme leader of the "International Year of Planet Earth" (IYPE) related to the topic of Deep Earth – from crust to core. She is President of the Mexican Society of Geomorphology and Chair of the Geomorphological Hazards Working Group of the International Association of Geomorphologists (IAG). She is a Member of the International Council for Science (ICSU) Committee on Scientific Planning and Review (CSPR), and of the International Consortium on Landslides. Recently she was elected as TWAS Young Affiliate Fellow, and at present she is Vice-President of the International Geographical Union (IGU).

ANDREW GOUDIE was Professor and Head of Department of Geography at Oxford University. A distinguished physical geographer, he was awarded a DSc by Oxford University, received a Royal Medal from the Royal Geographical Society, the Prize of the Royal Belgian Academy, the British Society for Geomorphology's David Linton Award (2009) and the Geological Society of America's Farouk El-Baz Award for Desert Research. He has been President of the Oxford University Development Programme, Pro-Vice-Chancellor of the University, and Delegate of Oxford University Press. He has recently been President of the Geographical Association, President of Section E of the British Association and Chairman of the British Geomorphological Research Group. Professor Goudie became Master of St Cross College, Oxford, in October 2003, and continues to lecture at the Oxford University Centre for the Environment.

Since 2005 he has been President of the International Association of Geomorphologists. In addition to being author of nearly 200 scientific papers, he is the author or co-author of the following books (amongst others): *The Human Impact*, *The Nature of the Environment*, *Environmental Change*, *The Encyclopedia of Global Change*, *Geomorphology of Deserts*, *Geomorphological Techniques*, *Chemical Sediments and Geomorphology*, *The Geomorphology of England and Wales*, *The Warm Desert Environment*, *Discovering Landscape in England and Wales*, *Landshapes*, *The Encyclopedic Dictionary of Physical Geography*, *Desert Geomorphology*, *The Student's Companion to Geography*, *The Earth Transformed*, *Aeolian Environments*, *Sediments and Landforms*, *The Encyclopedia of Geomorphology*, *The Oxford Companion to Global Change* and *Wheels Across the Desert*.

Cambridge University Press
978-0-521-76925-9 - Geomorphological Hazards and Disaster Prevention
Irasema Alcántara-Ayala and Andrew S. Goudie
Frontmatter
[More information](#)

Geomorphological Hazards and Disaster Prevention

Irasema Alcántara-Ayala

Universidad Nacional Autónoma de México, Mexico City

Andrew S. Goudie

St Cross College, Oxford



Cambridge University Press
978-0-521-76925-9 - Geomorphological Hazards and Disaster Prevention
Irasema Alcantara-Ayala and Andrew S. Goudie
Frontmatter
[More information](#)

CAMBRIDGE UNIVERSITY PRESS

Cambridge, New York, Melbourne, Madrid, Cape Town, Singapore,
São Paulo, Delhi, Dubai, Tokyo

Cambridge University Press
The Edinburgh Building, Cambridge CB2 8RU, UK

Published in the United States of America by Cambridge University Press, New York

www.cambridge.org

Information on this title: www.cambridge.org/9780521769259

© Cambridge University Press 2010

This publication is in copyright. Subject to statutory exception
and to the provisions of relevant collective licensing agreements,
no reproduction of any part may take place without the written
permission of Cambridge University Press.

First published 2010

Printed in the United Kingdom at the University Press, Cambridge

A catalogue record for this publication is available from the British Library

ISBN 978-0-521-76925-9 Hardback

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.

Contents

<i>List of contributors</i>	<i>page x</i>
I Introduction	1
ANDREW S. GOUDIE	
Part I Processes	3
2 Regional seismic shaking hazards in mountains	5
WILLIAM B. BULL	
2.1 Introduction	5
2.2 Lichenometry site characteristics	5
2.3 Regional seismic shaking	8
2.4 Conclusions	11
3 Volcanic hazards and risks: a geomorphological perspective	13
JEAN-CLAUDE THOURET	
3.1 Introduction	13
3.2 Direct volcanic hazards around active volcanoes	14
3.3 Indirect volcanic hazards and geomorphic impact	20
3.4 Post-eruption geomorphic impacts and responses	22
3.5 Long-term geomorphic hazards around inactive volcanoes	24
3.6 Methods and goals of volcano hazard and risk assessment	25
3.7 Concluding remarks and perspectives	28
4 Mountain hazards	33
OLAV SLAYMAKER	
4.1 Introduction to mountain geomorphic hazards	33
4.2 Site scale	34
4.3 Drainage basin scale	35
4.4 Global scale	40
4.5 Conclusion in light of accelerating environmental change	43
4.6 Conclusions	44

5 Review and future challenges in snow avalanche risk analysis	49
MICHAEL BRÜNDL, PERRY BARTELT, JÜRIG SCHWEIZER, MARGRETH KEILER AND THOMAS GLADE	
5.1 Background	49
5.2 Review and recent trends in hazard analysis	51
5.3 Methods of risk analysis	54
5.4 Change in avalanche risk, influence of different risk factors	56
5.5 Conclusions: where to go from here; future challenges	58
6 Landslide hazards	63
DAVID PETLEY	
6.1 Introduction	63
6.2 Landslide causes and triggers	64
6.3 The role of geomorphology in landslide hazard management	66
6.4 Terrain mapping	66
6.5 Susceptibility analysis	67
6.6 Hazard and stability analyses	68
6.7 Monitoring, behaviour prediction and warning systems	69
6.8 Secondary hazards and sediment production	70
6.9 Conclusions	72
7 Catastrophic landslides and sedimentary budgets	75
MONIQUE FORT, ETIENNE COSSART AND GILLES ARNAUD-FASSETTA	
7.1 Catastrophic landslides: definition, modes of emplacement and geomorphic significance	75
7.2 Geomorphic impacts of catastrophic landslides	78
7.3 Forecasting and preventing	82
7.4 Conclusions	83
8 Landslides and climatic change	87
LISA BORGATTI AND MAURO SOLDATI	
8.1 Introduction	87
8.2 Conceptual framework	88
8.3 Landslides and climate: state of the art	90
8.4 Conclusions: landslides in a changing environment; issues and perspectives	91
9 The hazardousness of high-magnitude floods	97
AVIJIT GUPTA	
9.1 Introduction	97
9.2 Flood climate	98
9.3 Non-meteorological floods	100
9.4 Flood physiography	101
9.5 Floods and geographical locations	102
9.6 Water and sediment transfer in floods	102
9.7 Source-to-sink passage of a flood	103

9.8	Types of flood hazard and their location	105
9.9	Conclusions: flood hazards and climate change	107
10	Flood hazards: the context of fluvial geomorphology	111
	GERARDO BENITO AND PAUL F. HUDSON	
10.1	Introduction	111
10.2	Fluvial geomorphology in flood hazard assessment	112
10.3	Flood hazards in the context of global climate change	119
10.4	Geomorphological adjustment to flood management	120
10.5	Flood hazard management: an integrated approach	122
10.6	Conclusions	123
11	Geomorphology and coastal hazards	129
	HARLEY J. WALKER AND MOLLY MCGRAW	
11.1	Introduction	129
11.2	Earthquakes, volcanic eruptions, and tsunami	133
11.3	Landslides	137
11.4	Meteorological events and coastal disaster	138
11.5	Other coastal hazards/disasters	139
11.6	Conclusions	142
12	Weathering hazards	145
	ANDREW S. GOUDIE AND HEATHER VILES	
12.1	Introduction	145
12.2	Salt weathering	146
12.3	Changing dimensions of the salt weathering hazard	148
12.4	Atmospheric pollution and weathering	149
12.5	Changing dimensions of the air pollution-induced weathering hazard	151
12.6	Fire, lightning and thermal fatigue	152
12.7	Mitigation	152
12.8	Conclusions	154
13	Hazards associated with karst	161
	FRANCISCO GUTIÉRREZ	
13.1	Introduction: why are hazards associated with karst important?	161
13.2	Sinkhole hazard	162
13.3	Other hazards associated with karst	170
13.4	Conclusions	173
14	Soil erosion	177
	ANDREW S. GOUDIE AND JOHN BOARDMAN	
14.1	Introduction: the nature of the problem	177
14.2	Forms of erosion	177
14.3	Rates of erosion: natural and anthropogenic	178
14.4	Assessment of current erosion	178
14.5	Consequences of erosion	179
14.6	Causation: soil erosion associated with deforestation and agriculture	180
14.7	Soil erosion produced by fire	180

viii Contents

14.8	Soil erosion associated with construction and urbanization	181
14.9	Humans or nature?	181
14.10	Soil erosion by wind	182
14.11	Global hotspots of erosion	183
14.12	Soil conservation: water erosion	183
14.13	Soil conservation: wind erosion	184
14.14	Conclusions	184
15	Desertification and land degradation in arid and semi-arid regions	189
	YANG XIAOPING	
15.1	Introduction	189
15.2	Regional-scale hazards and causes	190
15.3	Global-scale hazards	194
15.4	Conclusions	196
16	Dune migration and encroachment	199
	ANDREW S. GOUDIE	
16.1	Introduction	199
16.2	Methods of study	199
16.3	Rates of dune movement	199
16.4	Control	200
16.5	Conclusions	201
Part II	Processes and applications of geomorphology to risk assessment and management	203
17	GIS for the assessment of risk from geomorphological hazards	205
	CEES J. VAN WESTEN	
17.1	Introduction	205
17.2	Spatial data requirements for risk assessment	206
17.3	Hazard assessment	212
17.4	Vulnerability and risk assessment	214
17.5	Risk management	216
17.6	Conclusions	218
18	Hazard assessment for risk analysis and risk management	221
	MICHAEL CROZIER AND THOMAS GLADE	
18.1	Approach	221
18.2	Basic concepts and issues	221
18.3	The contribution of geomorphology to hazard assessment	224
18.4	Conclusions and perspectives	229

19 Vulnerability analysis in geomorphic risk assessment	233
GABI HUFSCHMIDT AND THOMAS GLADE	
19.1 Rationale	233
19.2 Different vulnerability approaches towards risk reduction	233
19.3 Science and technology	233
19.4 The human ecology approach	234
19.5 Vulnerability and the applied sciences	236
19.6 Vulnerability and the structuralist paradigm	237
19.7 Summary and perspectives	239
20 Geomorphological hazards and global climate change	245
ANDREW S. GOUDIE	
20.1 Introduction	245
20.2 Coastal hazards	246
20.3 Hydrological hazards	248
20.4 Mass movement and soil erosion hazards	250
20.5 Glacial and permafrost hazards	250
20.6 Aeolian hazards	251
20.7 Conclusions	252
21 Geomorphic hazards and sustainable development	257
DAVID HIGGITT	
21.1 Introduction	257
21.2 Challenges to the dominant paradigm of natural hazards	258
21.3 Vulnerability and resilience: Asian earthquakes	259
21.4 Geomorphology, hazards and sustainability	262
21.5 Flood hazards in Southeast Asia: links with sustainable management	265
21.6 Conclusions	266
22 Geomorphology and disaster prevention	269
IRASEMA ALCÁNTARA-AYALA	
22.1 Geomorphological hazards	269
22.2 Disasters: the international framework	270
22.3 1900–2000: beyond a century of disasters	272
22.4 Geomorphology: a brief account of contributing research, methodologies and techniques	275
22.5 Conclusions: the future agenda	276
23 Geomorphology and the international agenda: concluding remarks	279
IRASEMA ALCÁNTARA-AYALA	
<i>Index</i>	282

Contributors

Irasema Alcántara-Ayala

Instituto de Geografía, UNAM
 Circuito Exterior, Ciudad Universitaria
 04510, Coyoacán, México, D.F.
 México

Gilles Arnaud-Fassetta

Université Paris-Diderot
 Case Postale 7001
 75205 Paris Cedex 13
 France

Perry Bartelt

Avalanches, Debris Flows and Rockfall Research Unit
 WSL Institute for Snow and Avalanche Research SLF
 Flüelastrasse 11
 CH-7260 Davos Dorf
 Switzerland

Gerardo Benito

Laboratorio de Geomorfología e Hidrología
 Centro de Ciencias Medioambientales, CSIC
 Serrano 115 dup.
 28006, Madrid
 Spain

John Boardman

Environmental Change Institute,
 School of Geography and the Environment
 South Parks Road
 Oxford, OX1 3QY
 UK

Lisa Borgatti

Dipartimento di Ingegneria delle Strutture, dei Trasporti,
 delle Acque, del Rilevamento, del Territorio
 Alma Mater Studiorum Università di Bologna
 Viale Risorgimento, 2
 41036 Bologna
 Italy

William B. Bull

6550 N. Camino Katrina
 Tucson, AZ, 85718-2022
 USA

Michael Bründl

Warning and Prevention Research Unit
 WSL Institute for Snow and Avalanche Research SLF
 Flüelastrasse 11
 CH-7260 Davos Dorf
 Switzerland

Etienne Cossart

UMR Prodig 8586 – CNRS
 Université Panthéon-Sorbonne (Paris 1)
 2 rue Valette,
 75005 Paris
 France

Michael Crozier

Victoria University of Wellington
 School of Geography, Environment and Earth Sciences
 PO Box 600
 Wellington
 New Zealand

Monique Fort

UMR Prodig 8586 – CNRS
 Université Paris Diderot (Paris7)
 Département de Géographie
 UFR GHSS, Case 7001
 75205 Paris Cedex 13
 France

Thomas Glade

Department of Geography and Regional Research
 University of Vienna
 Universitaetsstr. 7
 A-1010 Vienna
 Austria

Andrew S. Goudie

St Cross College
 St Giles
 Oxford, OX1 3LZ
 UK

Contributors

xi

Avijit Gupta

School of Geography
 University of Leeds
 Leeds, LS2 9JT
 UK

Francisco Gutiérrez

Universidad de Zaragoza
 Departamento de Ciencias de la Tierra
 Edificio Geológicas
 C/. Pedro Cerbuna, 12
 50009 Zaragoza
 Spain

David Higgitt

Department of Geography
 National University of Singapore
 1 Arts Link, Kent Ridge
 117570 Singapore

Paul F. Hudson

Department of Geography and the Environment
 University of Texas at Austin
 Austin, TX 78712
 USA

Gabi Hufschmidt

School of Geography
 Victoria University of Wellington
 P.O. Box 600
 Wellington
 New Zealand

Margreth Keiler

Department of Geography and Regional Research
 University of Vienna
 Universitaetsstr. 7
 A-1010 Vienna
 Austria

Molly McGraw

Southeastern Louisiana University
 SLU-10686
 Hammond, LA 70402
 USA

David Petley

Durham University
 Department of Geography, Science Laboratories
 South Road
 Durham, DH1 3LE
 UK

Jürg Schweizer

Snow and Permafrost Research Unit
 WSL Institute for Snow and Avalanche Research SLF
 Flüelastrasse 11
 CH-7260 Davos Dorf
 Switzerland

Olav Slaymaker

University of British Columbia
 Department of Geography
 1984 West Mall
 Vancouver, V6T 1Z2
 Canada

Mauro Soldati

Dipartimento di Scienze della Terra
 Università di Modena e Reggio Emilia
 Largo S. Eufemia, 19
 41121 Modena
 Italy

Jean-Claude Thouret

Laboratoire Magmas et Volcans UMR 6524 CNRS et
 OPGC
 Université Blaise Pascal Clermont II
 5 rue Kessler
 63038 Clermont-Ferrand Cedex
 France

Cees J. van Westen

International Institute for Geo-Information Science and
 Earth Observation (ITC)
 Hengelosestraat 99
 PO Box 6
 7500 AA Enschede
 The Netherlands

Heather Viles

School of Geography and the Environment
 South Parks Road
 Oxford, OX1 3QY
 UK

Harley J. Walker

Department of Geography and Anthropology
 Louisiana State University
 Baton Rouge, LA 70803
 USA

YANG Xiaoping

Institute of Geology and Geophysics
 Chinese Academy of Sciences
 P.O. Box 9825
 Beijing 100029
 China