

Advances in Natural and Technological Hazards Research

Volume 49

More information about this series at <http://www.springer.com/series/6362>

Nirupama Agrawal

Natural Disasters and Risk Management in Canada

An Introduction

 Springer

Nirupama Agrawal
York University
Toronto, ON, Canada

ISSN 1878-9897 ISSN 2213-6959 (electronic)
Advances in Natural and Technological Hazards Research
ISBN 978-94-024-1281-9 ISBN 978-94-024-1283-3 (eBook)
<https://doi.org/10.1007/978-94-024-1283-3>

Library of Congress Control Number: 2018937409

© Springer Science+Business Media B.V., part of Springer Nature 2018

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, express or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Disclaimer: The facts and opinions expressed in this work are those of the author(s) and not necessarily those of the publisher.

Printed on acid-free paper

This Springer imprint is published by the registered company Springer Science+Business Media B.V. part of Springer Nature.

The registered company address is: Van Godewijkstraat 30, 3311 GX Dordrecht, The Netherlands

*To my late parents, Dr. Jageshwar Sharan
Agrawal and Snehlata Agrawal*

Foreword

One of the greatest challenges faced by the governments of all countries today lies in creating institutional convergence that integrates global goals emanating from the Sustainable Development Goals, the Sendai Framework for Disaster Risk Reduction, the Paris Agreement on Climate Change, and the World Humanitarian Summit. Disaster risk reduction and climate change adaptation are part of key agendas pursued in all these recent global agreements. The effective reduction of losses and risks stemming from natural hazards and climate extremes requires an integrated action at various levels of government and involves a wide range of stakeholders.

Canadians in all regions are exposed to risk from natural disasters. As Canada's natural and social environment changes, the complexity of managing the consequences of disasters also increases due to the ever-greater technological dependencies and interdependencies.

This is the context for this book, which puts the spotlight on the broad range of natural hazards that threaten Canada but also on the strategies and more practical actions that can challenge conventional perceptions of risk and inform decision-making to arrive at a more effective disaster risk reduction and resilience building.

In this extensive treatment of the subject, Dr. Nirupama Agrawal explores hazards from the small and medium scale such as erosion, landslides, and blizzards to the large scale such as epidemics, droughts, and earthquakes. The book systematically defines these key threats and explores their potential impacts on Canada.

After establishing the types and levels of threats to Canada, Dr. Agrawal proceeds to explore the many ways in which society must tackle these growing risks. Drawing upon a diverse body of literature that includes many disciplines and fields of study, the book investigates the interrelated concepts of disaster risk management and disaster resilience and considers the importance of risk perception by various groups. It argues that an all-hazard, risk-based, problem-solving, and results-oriented approach should be pursued in disaster risk reduction to address the multifactorial and interdependent nature of the disaster risk chain, identify relevant solutions, and optimize the use of resources.

Subsequent chapters describe a range of qualitative and quantitative methods that can provide a comprehensive approach to understanding disaster risk and vulnerabilities and inform decision-making to build more resilient communities. The book consistently draws upon examples and case studies from around the world, recognizing that both the challenge of disaster risk and the potential solutions can be found globally.

Although this book is entitled *An Introduction*, Dr. Agrawal must be commended for providing such comprehensive but also accessible insights into national disasters and risk management in Canada. It is our hope that this book will raise awareness and motivation across Canada and beyond, to find rational, balanced responses to these mounting threats to humankind.

University of Huddersfield
Huddersfield, UK

Professor Richard Haigh
Professor Dilanthi Amaratunga

Foreword

It gives me great pleasure to write the preface for this excellent monograph titled *Natural Disasters and Risk Management in Canada: An Introduction*, written by Professor Nirupama Agrawal of York University. I have known her for the past 12 years and have interacted with her professionally during this period. This is a first of its kind publication emphasizing disasters and disaster management in the Canadian context. The monograph is very relevant and timely in view of the ever-increasing vulnerability of the Canadian population to a variety of natural hazards. This monograph consists of eight chapters, and together they portray a comprehensive view and state of the art in disaster management in general and in Canada in particular.

Chapters 1 and 2 deals with a variety of natural hazards, such as earthquakes, landslides, hurricanes, ice storms, storm surges, tsunamis, floods, droughts, etc. Chapter 3 has the title “Disaster Risk Management” and discusses risk analysis, strategic planning, rehabilitation, and sustainable development. Chapter 4 is about disaster resilience and provides details about community resilience and decision support systems. Chapter 5 is about disaster perception and includes topics such as perceptions of risk, vulnerability, and emergency measures. Chapters 6 and 7 explain quantitative disaster risk evaluation methods practiced in Canada and around the world. Finally, Chap. 8 discusses qualitative methods to evaluate disaster risk. As one can see, this monograph provides very valuable information and data on a variety of natural hazards that can happen and happened in the past in Canada.

The bibliography is extensive and up to date, and the illustrations and tables add particular value to the contents of the monograph. I believe that this monograph will be very useful not only to the practitioners of disaster management but also to

research scholars, graduate students, and the general public who are interested in natural disasters. I strongly feel that this should be in the personal collection of people interested in natural disasters and also should be in the library of scholarly institutions specializing in disaster research and mitigation.

Department of Civil Engineering
University of Ottawa
Ottawa, ON, Canada

Tad S. Murty

Preface

When York University launched a postsecondary program in the then-nascent discipline of disaster and emergency management in 2005, Canada had only one other undergraduate-level program in the field, at Brandon University. The discipline not only needed recognition, but given its complex and multifaceted nature, teaching and research resource material needed to be developed. Areas such as climate change, natural disasters, early warning systems, risk and vulnerability assessment, and humanitarian aid were essential to the curriculum. Although I found scholarly material developed by many government organizations in the USA and Canada and other well-known organizations (e.g., the World Health Organization, Munich Re, ReliefWeb, UN International Strategy for Disaster Reduction, Red Cross, etc.), I couldn't find everything I wanted for my classes in one place. So, this project was conceived out of the need to develop a course material for university-level degree programs, both undergraduate and graduate, on disasters, risks, vulnerability, and resilience for disaster risk reduction.

The book is divided into eight chapters. Chapters 1 and 2 deal with natural hazards, which are categorized by their size and impact as large-, medium-, or small-scale hazards. Chapter 1, "Defining Natural Hazards: Large-Scale Hazards," deals with droughts, earthquakes, extreme weather, floods, forest fires, ice storms, hurricanes, and biophysical hazards. Chapter 2, "Defining Natural Hazards: Medium- and Small-Scale Hazards," focuses on medium-scale hazards such as erosion, landslides, snowstorms/blizzards, subsidence, sinkholes, tornados, and windstorms and small-scale hazards, namely, extraterrestrial hazards, fog, geomagnetic storms, hailstorms, and lightning. Notably, tsunamis and volcanoes are excluded from these two chapters, as they are rarely a concern in Canada. Chapter 3, "Disaster Risk Management," discusses risk analysis strategic planning

and sustainable development, drawing extensively on case studies and examples to do so. Decision support systems and the decision-making process are also integral parts of this chapter. Chapter 4, “Disaster Resilience,” sheds light on the concept of resilience and related discussions on sustainable livelihood and community participation. Representative research studies are also included, supplementing these discussions. Chapter 5, “Disaster Perceptions,” explores various aspects of perceptions such as disaster risk, vulnerability, and people, including influencing factors. In turn, Chapter 6, “Disaster Risk Evaluation: Quantitative Methods in Canada,” highlights various methods and tools used by professionals to estimate the likelihood and consequences of hazards. Chapter 7, “Disaster Risk Evaluation: Other Quantitative Methods,” describes tools and approaches developed in the USA (FEMA) and New Zealand and at the United Nations University. In closing, Chapter 8, “Disaster Risk Evaluation: Qualitative Methods in Canada,” covers disaster models that account for a variety of aspects including the subjective and dynamic nature of risk and vulnerabilities over space and time, access to resources, and community perceptions of hazard-related risks.

The material compiled here is based on decades of my own research with colleagues and graduate students and includes examples and applications of various concepts and methodologies – existing and newly developed. Accordingly, numerous case studies constitute an integral part of this book. In addition, the Canadian federal government and provinces are increasingly taking a keen interest in hazard identification and risk assessment as a policy measure to mitigate disaster impact. This renewed focus on the part of the government is a testament to the importance of this field in light of the growing cost of disasters in Canada and around the globe.

Toronto, ON, Canada

Nirupama Agrawal

Acknowledgements

This book could not have been written without the support and guidance of Dr. Tad Murty, my mentor, collaborator, and colleague. He encouraged, challenged, and believed in me throughout the research and writing process – for which I thank him sincerely. I wish to express my profound gratitude to Professor Richard Haigh and Professor Dilanthi Amaratunga, University of Huddersfield, for inspiring me with their research and for graciously agreeing to contribute the foreword; to Dr. Kumaraswamy Ponnambalam, University of Waterloo, for his careful review of the manuscript; and to Petra van Steenbergen, executive editor at Springer, for her incredible patience with me. I am also grateful to my numerous coauthors, collaborators, colleagues, and students over the years, as they have helped me tremendously through their knowledge and passion for the subject matters covered in this book, and I would especially like to thank Dr. Slobodan Simonovic, Western University, for his enduring support. Lastly, I am grateful to my family and friends for always being there for me when I need them most and to my two daughters, Nita and Nandita, whose unconditional love has always been my true strength.

Contents

1	Defining Natural Hazards – Large Scale Hazards	1
1.1	Definitions of Selected Large Scale Natural Hazards	1
1.2	Biophysical (health) Hazards	2
1.2.1	Epidemic	3
1.2.2	Pandemic	3
1.3	Drought	6
1.4	Earthquake	9
1.4.1	Earthquake Measurement and Monitoring	10
1.4.2	Earthquake Zones in Eastern Canada	11
1.4.3	Potential Impacts	12
1.5	Extreme Weather – Heat Wave and Cold Wave	14
1.5.1	Heat Wave	14
1.5.2	Cold Wave	16
1.6	Floods	17
1.6.1	Case Study – Toronto, Canada	18
1.6.2	Case Study – Flood Risk and Urbanization of London, Ontario	22
1.7	Forest Fire/Wildfire	23
1.8	Ice Storm	24
1.8.1	Case Study – Urban Impacts of Ice Storm of December 2013, Toronto, Canada	25
1.9	Hurricane	32
1.9.1	Hurricane Return Periods	33
1.9.2	Hurricane Intensity	33
1.9.3	Case Study – Hurricane Hazel – Toronto, Canada	37
1.9.4	Case Study – Hurricane Sandy, New York, USA	37
1.10	Exercise	38
	References	38

2 Defining Natural Hazards – Medium and Small Scale Hazards 41

2.1 Medium Scale Hazards 41

2.1.1 Erosion 41

2.1.2 Landslide 42

2.1.3 Snowstorm/Blizzard 50

2.1.4 Subsidence and Sinkhole 53

2.1.5 Tornado 55

2.1.6 Windstorm 62

2.2 Small Scale Hazards 68

2.2.1 Extraterrestrial Hazard 68

2.2.2 Fog 73

2.2.3 Geomagnetic Storm 73

2.2.4 Hail Storm 74

2.2.5 Lightning 76

2.2.6 Exercise 78

References 78

3 Disaster Risk Management 81

3.1 Disasters 81

3.2 Risk 82

3.3 Disaster Risk Management – Key Elements 84

3.4 Threat Recognition 84

3.5 Risk Analysis and Assessment 85

3.5.1 Case Study – A Multi-tier Hazard in Northern India in 2013 86

3.6 Risk Control Options 91

3.6.1 Case Study – London, Canada 92

3.6.2 Case Study – Red River Basin, Manitoba, Canada 95

3.7 Strategic Planning 105

3.7.1 Case Study – The 2004 Indian Ocean Tsunami 109

3.8 Response, Recovery, Reconstruction, and Rehabilitation 111

3.8.1 Case of Vertical Evacuation Shelters in India 112

3.8.2 Case Discussion – California 117

3.8.3 Case of Nepal – Post-earthquake Reconstruction 118

3.8.4 Case of Indian Ocean Tsunami 2004 – India 119

3.9 Knowledge Management and Sustainable Development 126

3.9.1 Case of Canadian Coasts – Arctic, Western, and Eastern 127

3.9.2 Case of Climate Change and Sunspots in Canada 131

3.9.3 Case Study – Propane Explosion in Toronto, Canada 133

3.10 Exercise 141

References 141

- 4 Disaster Resilience** 147
 - 4.1 Resilience 147
 - 4.2 Community Resilience 152
 - 4.2.1 Case Study Based on Events in Canada, Japan and New Zealand 154
 - 4.2.2 Case Study Based on a Women’s Group in Toronto, Canada 157
 - 4.2.3 Case Study Based on Women’s Training Group in Pakistan 160
 - 4.3 Resilience of the Built Environment 165
 - 4.4 Decision Support Tool For Estimating Resilience 167
 - 4.4.1 Data Requirement 168
 - 4.5 A New and Comprehensive Approach to Evaluate Resilience 173
 - 4.5.1 A Canadian Case Study to Demonstrate the Approach 174
 - 4.5.2 Findings – Resilience Maps 184
 - 4.6 Exercise 186
 - References 187
- 5 Disaster Perceptions** 193
 - 5.1 Perception of Risk 193
 - 5.1.1 Media’s Influence on Risk Perception 200
 - 5.2 Perception of Vulnerability 200
 - 5.3 Perception of People 202
 - 5.3.1 Case Studies 205
 - 5.4 Perspectives of Emergency Managers 208
 - 5.4.1 Highlights of the Findings 210
 - 5.5 Exercise 214
 - References 214
- 6 Disaster Risk Evaluation – Quantitative Methods in Canada** 219
 - 6.1 Hazard Identification and Risk Assessment Method 219
 - 6.1.1 Purpose 220
 - 6.1.2 Scope 220
 - 6.1.3 Structure of the HIRA Process (Fig. 6.1) 221
 - 6.1.4 Application of HIRA for Hazards in Ontario, Canada 224
 - 6.2 Hazard Risk and Vulnerability Assessment Tool 226
 - 6.2.1 Purpose 228
 - 6.2.2 Objective 230
 - 6.2.3 Steps Required for HRVA 230
 - 6.2.4 Understanding Hazards 233
 - 6.2.5 Identification of Vulnerabilities 233
 - 6.2.6 Impact Assessment and Ranking 236
 - 6.2.7 Case Studies on the Application of the HRVA 238
 - 6.3 All Hazards Risk Assessment Method 253
 - 6.3.1 Purpose 253

- 6.3.2 Overview of the AHRA Process 254
- 6.3.3 AHRA Business Cycle (Fig. 6.19) 254
- 6.4 Exercise 268
- References 268
- 7 Disaster Risk Evaluation – Other Quantitative Methods 271**
 - 7.1 Federal Emergency Management Agency Method 271
 - 7.1.1 Timing and Duration of Disruption 273
 - 7.1.2 Conducting the BIA 274
 - 7.1.3 Resources Required to Supporting Recovery Strategies 276
 - 7.1.4 Testing & Exercises 277
 - 7.2 SMUG Model 278
 - 7.2.1 Seriousness 278
 - 7.2.2 Manageability 279
 - 7.2.3 Urgency 279
 - 7.2.4 Growth 279
 - 7.2.5 Application of the SMUG Model 279
 - 7.2.6 Challenges in Prioritizing Hazards 281
 - 7.2.7 Case Study: Risk Profile for Chatham Islands 282
 - 7.3 World Risk Index Tool 284
 - 7.4 Role and Assessment of Return Period 285
 - 7.4.1 Working Exercise to Calculate Return Period 288
 - 7.5 Exercise 291
 - References 292
- 8 Disaster Risk Evaluation – Qualitative Methods 295**
 - 8.1 Pressure and Release (PAR) Model 295
 - 8.1.1 Application of Pressure and Release (PAR) Model to the Case of Hurricane Katrina 296
 - 8.1.2 Application of PAR Model to the 2008 Sichuan, China Earthquake 297
 - 8.2 Access to Resources (ATR) Model 299
 - 8.2.1 Application of Access to Resources Model to the Case of Hurricane Katrina 305
 - 8.3 Community Perception Model 306
 - 8.3.1 Application of Community Perception Model 309
 - 8.3.2 Comparison of Community Perception Model with Conventional Approach 312
 - 8.4 Risk Aversion Concept 313
 - 8.5 Exercise 314
 - References 314

Contents	xix
Appendices	317
Glossary and Definitions of Terms	345
Learning Objectives	355
Index	357