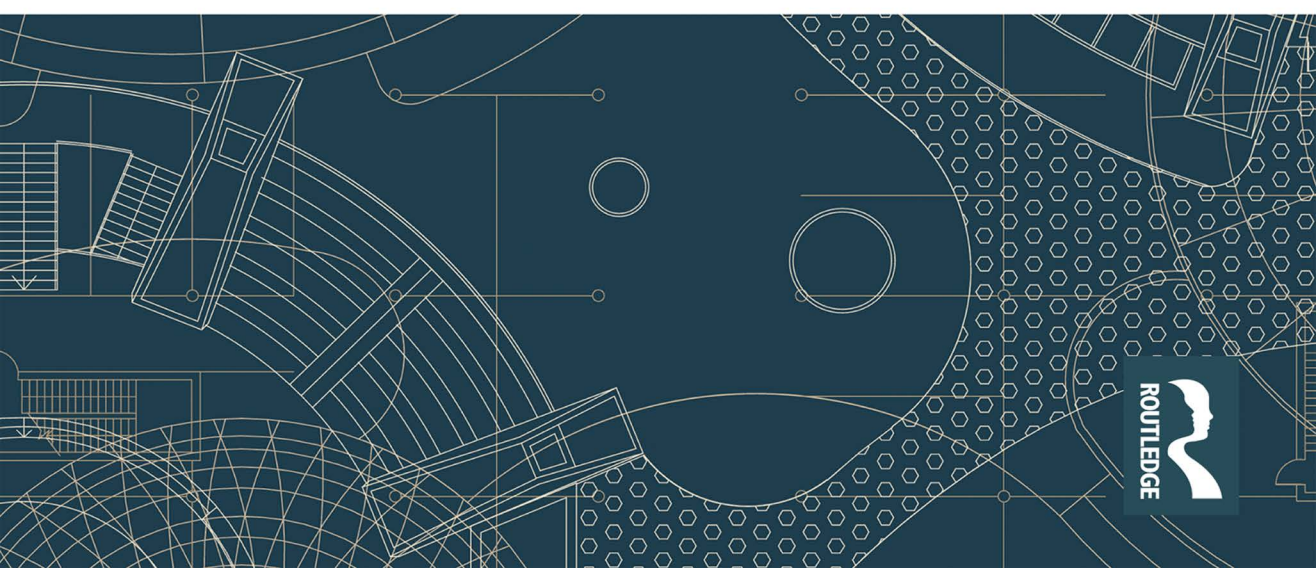
URBAN FLOOD MITIGATION STRATEGIES USING GEOSPATIAL TOOLS

A PRACTICAL APPROACH FOR CITIES AND TOWNS OF THE DEVELOPING WORLD

Narendar Kumar



Urban Flood Mitigation Strategies Using Geospatial Tools

The disastrous effects of floods in urban areas of various Indian cities have been increasing in severity and extent over the past decade. This book explores flood disasters, their impact in world and Indian contexts, assessing vulnerability and risks involved, and systematic use of geographic information system (GIS)-enabled platforms to map mitigation measures sustainably, with special reference to the metropolitan flood mitigation endeavors.

This book balances the theoretical with empirical approaches to form a unique standpoint on the various challenges and possible solutions to urban flooding in India. Through a study of major urban flood incidents, this book analyzes the factors which contribute to the rising risk of flooding with increasing urbanization, population dynamics, growth, and urban sprawl, with particular focus on the cities of Chennai, Mumbai, and Hyderabad in India. It also examines disaster governance on urban floods and legislative prospects of flood disasters through discussions on standing acts, United Nations (UN) directives, and internationally adopted practices and actions, which are applicable in the Indian context.

An interdisciplinary study, this book brings together tools and research from various disciplines including geography, urban and regional planning, and GIS. It will be an invaluable resource for researchers, scholars, engineers, students, planners, academicians, and professionals of cross-disciplines to help them resolve the problem of urban flooding. It will also be of interest to the general reader seeking to learn more about disasters, urban flooding, engineering, and GIS.

Narendar Kumar is working as an urban planner with the Sustainable Cities & Transport program at World Resources Institute (WRI) India and lives in village Lasedi of district Churu, Rajasthan, India. He is a trained geographer and spatial planner with four years of experience in the fields of urban and regional planning. He has worked at the School of Planning and Architecture, New Delhi; Malaviya National Institute of Technology, Jaipur; IIT-Guwahati; and Nagpur Municipal Corporation for various projects of town planning. He has largely worked on the preparation of master plans, regional plans, and zonal development plans. He has also worked on the Zonal Master Plan of Nahargarh Wildlife Sanctuary and Eco-Sensitive Zone, and the National Rurban Mission, Government of India. Additionally, he was engaged as an assistant professor as a visiting faculty member at Jagannath University, Jaipur, where he taught in the M.Tech urban planning discipline. Mr. Kumar is an honored life associate of the Institute of Town Planners, India (ITPI), New Delhi, and he is interested in teaching, research, writing books and monographs, and learning across disciplines.

Urban Flood Mitigation Strategies Using Geospatial Tools

A Practical Approach for Cities and Towns of the Developing World

Narendar Kumar

Routledge
Taylor & Francis Group
LONDON AND NEW YORK

First published 2024
by Routledge
4 Park Square, Milton Park, Abingdon, Oxon OX14 4RN

and by Routledge
605 Third Avenue, New York, NY 10158

Routledge is an imprint of the Taylor & Francis Group, an informa business

British Library Cataloguing-in-Publication Data
A catalogue record for this book is available from the British Library

ISBN: 978-1-032-49567-5 (hbk)
ISBN: 978-1-032-55065-7 (pbk)
ISBN: 978-1-003-42885-5 (ebk)

DOI: 10.4324/9781003428855

Typeset in Sabon
by Apex CoVantage, LLC

Contents

Figures

Tables

Foreword

Urban flooding is the most widespread problem in most Indian cities and towns. I strongly consider that the use of GIS technology brings accuracy to spatial planning. In this book, it is demonstrated how to use a GIS-based hydraulic model to create a flood mitigation strategy for the study area in Hyderabad city, India. These applications include watershed delineation, hydrological analysis, the grid pattern of streams, their order, networking, and numbering. It presents well-organized prior information on disasters with technical approaches in a very systematic and organized manner for the readers.

The results depict an understanding of the relationship between fast urbanization and urban flooding taking examples of three cities—namely, Chennai, Mumbai, and Hyderabad—which are elaborately discussed. Additionally, to comprehend the problems with urban floods, a thorough examination of the underlying causes and threats to the urban infrastructure is covered. Eventually, it identifies unplanned urbanization, land use change, and poor watershed management as important issues for consideration to the increased risk of urban floods with illustrations and the latest data.

This book emphasizes the importance of balancing theoretical and empirical approaches, which sets it apart from other texts. In addition, the book discusses disaster management, governance, and legislative prospects of disaster response through adopted United Nations (UN) and international frameworks related to the Indian context.

This book concludes with a demonstration of how GIS technology can be applied effectively in a core part of Hyderabad city, India. The study area has a low-lying topography, is heavily built up, is highly populated with a long history of flooding incidents, and is frequently under serious threat of floods with all their adverse impacts. This volume brings out the usefulness of GIS techniques to identify and resolve problems by developing a framework for a systematic investigation that may be equally relevant for other cities and towns from the developing world. All of this book's chapters are structured logically, integrated around a coherent central theme, and closely interlinked. It encourages readers to read the subsequent chapters to enhance their learning about the complete process of urban flood analysis.

Prof. Dr. S Kumar
Hyderabad, India
January 2023

Preface

I am glad to write this book, which will provide a framework for learning about the skills that emphasize the uniqueness of groups and individuals to mitigate flooding in urban areas. In my opinion, there has been a very short-sounding knowledge\ which elucidates urban flood mitigation strategies integrating with the disciplines of urban planning, engineering, and applications of GIS-enabled platforms which can deliver a unique but also perfect sense to the readers. The original idea of writing this book is drawn from my thesis for M.Tech. during urban and regional planning study. Later on, I realized that being a research monograph, it can be a prominent publication in the field of urban planning providing a comprehensive knowledge of urban flood management systematically and sustainably.

Although I have reviewed recent publications mostly useful for the United Kingdom, Europe, and the developed world which are almost all taken from the collective articles from several authors and edited into a single book that lacks coherence and legibility in a more focused and single-context approaching to resolve the issues of urban flooding. On the other hand, few books are authored works dealing with the same developed nations and talking about highly advanced computing techniques and model-based terms which are also not comprehensible by cross-discipline persons without any information and prior knowledge of those engineering terms and processes, particularly for the social scientists who aim for the human-centric approach.

I felt both the preceding issues and tried to write this book which can integrate the theoretical and practical approaches demonstrating the uses of GIS in a single book presenting well-organized prior information on disasters with technical approaches in a very systematic and organized manner for the readers.

The book admires the due perspective of lay readers who are not experts in many technical interventions and do not have prior sound knowledge of disasters, urban flooding, engineering, and GIS. Therefore, all the chapters are structured logically and integrated around a coherent central theme that has legibility and motivates readers to view the subsequent chapters to enhance their understanding of the complete process of urban flood mitigation.

Eventually, this book will be glorified as a referential document to widely understand the disasters, vulnerability, risk, and multiway impacts carried out by various disasters, with vital examples from the world and Indian contexts with the latest data. Furthermore, it depicts disaster management, disaster governance, legislative perspectives, and policies in the Indian context including standing acts of the UN and similar international agendas and frameworks on flood disasters adopted in the Indian context, narrowing

it to urban flooding. This book also tries to deliver an intellectual understanding of the rising risk of flooding with increasing urbanization, population dynamics, growth, and urban sprawl of Chennai, Mumbai, and Hyderabad city, including their major flood incidents to make it more contextualized.

Apart from this, the elaborated flood impact analysis, mitigation measures, use of GIS-enabled platforms, and many other aspects to achieve flood mitigation endeavors are systematically discussed based upon the baseline data of empirical approaches, which provide importance to this book. The cutting-edge solution and practical approaches to mitigate urban flooding discussed in this book may be equally applicable to such cities and towns from the developing world. This book will be equally useful to research scholars, engineers, planners, architects, graduate and postgraduate students, academicians, policymakers, and professionals of cross-disciplines throughout the world who practice exploring the way to solve the problem of urban flooding.

Narendar Kumar
Lasedi, Sadulpur
Rajasthan, India
February 2023

Acknowledgments

I am deeply indebted to my grandfather late Shri Fateh Singh and my father Pawan Chhimpa, whose life experiences and conduct taught me how to navigate difficulties with both dignity and sincerity, and motivated me toward excelling in my career despite all odds. This book would not have been possible without these learnings. I am immensely grateful to my beloved wife Rajbala Chhimpa for her unconditional kindness, care, and support. I am also thankful to my nephew and niece, Himank and Charu, and wish them the very best in life.

I would also like to thank Prof. Santhanam Kumar from JNAFA University, Hyderabad, for his advice and guidance at every stage of this publication. I am also thankful to Prof. Ashok Kumar and Rabidyuti Biswas from the School of Planning and Architecture, New Delhi for providing moral and motivational support during the early stages of my career. I would like to express profound gratitude to Prof. Bhupender Singh, who has always been a guardian figure, and to all other teachers for their faith in me during my studentship.

I would also like to thank my friends Mohit Sai, Akash, Pramod, Mandip, Nitin Singh, WRI India colleagues, and others who have always encouraged me. A special thanks to Tanmay Dev, who helped me ideate and make this research more cogent.

I also appreciate the editorial board, and two anonymous reviewers for their helpful advice and insightful feedback. At Routledge, the commissioning manager (Shoma Choudhury), senior commissioning editor (Amit Kumar), project and production manager, copyeditor, and their colleagues were kind, prompt, and helpful throughout the process.

Narendar Kumar
Lasedi, Sadulpur
Rajasthan, India
February 2023

Annexures

Acronyms

1D	One-Dimensional
2D	Two-Dimensional
3D	Three-Dimensional
AHP	Analytical Hierarchical Process
AMCDRR	Asian Ministerial Conference on Disaster Risk Reduction
ARGs	Automatic Rainfall Gauges
BGI	Blue-Green Infrastructure
BIS	Bureau of Indian Standards
BMC	Brihan Mumbai Municipal Corporation
BMTPC	Building Materials & Technology Promotion Council
BRO	Border Road Organization
BT	Bituminous
CBOs	Community-Based Organizations
CDMPs	City Disaster Management Plans
CIDCO	City and Industrial Development Corporation
cm	centimeter
CMA	Chennai Metropolitan Area
CoP	Conference of the Parties
COVID	Coronavirus Disease
CRED	The Centre for Research on the Epidemiology of Disasters
CRZ	Coastal Regulation Zone
CWC	Central Water Commission
CWG	Commonwealth Games Village
DEM	Digital Elevation Model
DMAs	Disaster Management Authorities
DM	Disaster Management
DMC	Disaster Management Cycle
DMSP	Disaster Management Support Programme
DPM	Disaster Preparedness and Management
DRM	Disaster Risk Management
DRR	Disaster Risk Reduction
DWR	Doppler Weather Radar
EEH	Eastern Express Highway
EIA	Environmental Impact Assessment
EM-DAT	Emergency Events Database
EMS	Emergency Medical System
EOCs	Emergency Operations Centers

FTL	Full Tank Level
GACC	Global Anthropogenic Climate Change
GDP	Gross Domestic Product
GHMC	Greater Hyderabad Municipal Corporation
GIS	Geographic Information System
GoI	Government of India
HFA	Hyogo Framework for Action
HH	Households
HUA	Hyderabad Urban Agglomeration
IDNDR	International Decade for Natural Disaster Reduction
IFRC	International Federation of Red Cross and Red Crescent Societies
IIHS	Indian Institute of Human Settlement
IIPA	Indian Institute of Public Administration
IMD	India Meteorological Department
INDC	Intended Nationally Determined Contributions
INR	Indian National Rupee
IPCC	Intergovernmental Panel on Climate Change
IRC	The Indian Road Congress
km	kilometer
LDEO	Lamont-Doherty Earth Observatory
LULC	Land Use & Land Cover
MCDM	Multi-Criteria Decision-Making
MCGM	Municipal Corporation of Greater Mumbai
MCH	Municipal Corporation of Hyderabad
MDAI	Modified Domestic Assets Index
MERS CoV	Middle East Respiratory Syndrome Coronavirus
MHADA	Maharashtra Housing and Area Development Authority
m	meter
mm	millimeter
MMRDA	Mumbai Metropolitan Region Development Authority
MoHA	Ministry of Home Affairs
MoHUA	Ministry of Housing and Urban Affairs
MoUD	Ministry of Urban Development
MRTH	Ministry of Road Transport and Highways
MSK Scale	Medvedev–Sponheuer–Karnik Scale or modified Mercalli Scale
N-CoV	Novel Coronavirus
NAPCC	National Action Plan on Climate Change
NDMA	National Disaster Management Authority
NCERT	National Council of Education Research and Training
NCRMP	National Cyclone Risk Management Project
NDMP	National Disaster Management Plan
NDRF	National Disaster Response Force
NEC	National Executive Committee
NFC	National Flood Commission
NH	National Highway
NICRA	National Initiative on Climate Resilient Agriculture
NIDM	National Institute of Disaster Management
NIUA	National Institute of Urban Affairs
NMSA	National Mission on Sustainable Agriculture

NOAA	(U.S.) National Oceanic and Atmospheric Administration
NPDM	National Policy on Disaster Management
NRSC	National Remote Sensing Centre
NSSL	The National Severe Storms Laboratory
NWS	National Weather Service
OG	Out Growth
ORR	Outer Ring Road
OSD	Officer on Special Duty
PRIs	Panchayati Raj Institutions
PTSD	Post-Traumatic Stress Disorder
RBA	Rashtriya Barh Ayog (National Flood Commission)
RH	Rainwater Harvesting
RWAs	Resident Welfare Association(s)
SARS-CoV	Severe Acute Respiratory Syndrome Coronavirus
SDGs	Sustainable Development Goals
SDMAs	State Disaster Management Authorities
SEC	State Executive Committee
SNDP	Strategic Nallah Development Program
SoI	Survey of India
SPV	Special Purpose Vehicle
SRSACs	State Remote Sensing Application Centers
SRTM	Shuttle Radar Topography Mission
SuDS	Sustainable Urban Drainage Systems
SWD	Stormwater Drains
SWMM	The Stormwater Management Model
SWOT	Strength, Weakness, Opportunity, and Threat
TERI	The Energy and Resources Institute
TIN	Triangulated Irregular Network
TPS	Town Planning Scheme
TRM	Total Risk Management
UA	Urban Agglomeration
UFC	Urban Flooding Cell
UFDM	Urban Flood Disaster Management
UFDRM	Urban Flood Disaster Risk Management
UFRI	Urban Flood Risk Index
ULBs	Urban Local Bodies
UN	United Nations
UNDP	United Nations Development Programme
UNDRR	United Nations Office for Disaster Risk Reduction
UNFCC	United Nations Framework Convention on Climate Change
UNISDR	United Nations International Strategy for Disaster Reduction
USAID	United States Agency for International Development
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
UTs	Union Territories
WEH	Western Express Highway
WMO	World Meteorological Organization
WRI	World Resources Institute
WRI	World Risk Index

1 Hazard, Disaster, and Vulnerability

1.1 Introduction

Disasters existed even before humans walked the Earth. However, the exponential increase in the number of disasters and the devasting impact that has been instigated by them in recent years has become a source of deep concern on a national as well as international scale. In the span of the last ten years or so, the number of these disasters, both natural as well as human-caused, has climbed relentlessly. The average number of disasters has increased from 428 disasters per year from 1994–1998 to 707 disasters per year from 1999–2003 (Vasilescu et al., 2008). This data indicates a sharp increase in the number of disasters per year by 60 percent. The situation is even worse in developing countries, which have seen an increase in disasters by 142 percent in the same time frame.

The Emergency Events Database (EM-DAT), one of the most reputed international platforms to record the datasets of such events, tracked 7,348 disaster events globally from 2000–2019 (CRED, 2019). In the past 20 years, there have been 367 disasters per year on average, while the average was 210 events per year for the period 1980–1999 when total disaster events were 4,212 (CRED, 2019). The EM-DAT data depicts that disaster events have almost doubled for the same time span of 20 years for the two different periods mentioned previously. An important calculation made by CRED (2020) states that 1.23 million lives have been claimed by disasters, which averages to about 60,000 lives per annum, and a total of four billion people have been affected in one way or another by disasters all over the world.

A United Nations (UN) report for ten nations released just before the International Day for Disaster Reduction, titled "Economic Losses, Poverty and Disasters 1998–2017" (India Today, 2018), reveals that the economic losses caused by disasters are valued at US$2,908 billion. From this, US$2,245 billion—or 77 percent of the total losses—can be credited to damage caused by climate-related disasters. This report elucidates that the highest economic losses caused by disasters were for the United States (US$944.80 billion), with storms being major natural calamities, followed by China (US$492.20 billion), with floods as the major calamity. Japan suffered the next highest losses (US$376.30 billion), followed by India (US$79.50 billion), Puerto Rico (US$71.70 billion), (US$57.90 billion), Italy (US$56.60 billion), Thailand (US$52.40 billion), France (US$48.30 billion) Germany (US$57.90 billion) and Mexico (US$46.50 billion) (India Today, 2018).

Given the international concern and importance of disasters and disaster management (DM), The Sendai Framework for Disaster Risk Reduction 2015–2030 was adopted at the Third UN World Conference on Disaster Risk Reduction in Sendai, Japan, on 18 March 2015. It aimed to prevent new disasters and reduce existing disaster risks

DOI: 10.4324/9781003428855-1

and impacts. Disasters occur due to a combination of hazards and vulnerability, so we would first need to understand what both terms mean to finally understand what disaster means. Hazard refers to environmental input in the form of volcanic activity, a microscopic pathogen, too much precipitation or maybe the lack of it, or even climatic changes both in the long term and short term. The damages and losses are functions in the context of hazard, exposure, and vulnerability. Virtually, no such thing exists to be known as a natural disaster; only natural hazards occur that turn into disasters.

Hazards that have their origins due to natural phenomena—which could be in the form of meteorological, geological, or even biological phenomena—would be termed natural hazards (i.e. flood or drought, earthquake, tsunami, windstorm, landslide). They can inflict loss on macro- or micro-levels, depending on the intensity of the phenomenon. On the other hand, a natural disaster is a catastrophe wherein an event of hazardous nature turns into a calamity that has a grave impact on the community in the form of damage to infrastructure, leaving behind casualties and the disruption of the systems in place, thus, hindering the ability of the affected community to function normally without any external aid (Petrucci, 2012). According to Fritz (1961: 655), disaster is "an event of grave nature which has happened within the confines of space and time due to which a society or some members of it go through a grievous time due to the physical harm and the disruption in the society, resulting in the impairment of essential functions of the society which has been affected". These phenomena exceed society's mediocre protections, which is why social infringement and physical damage happen (Kreps, 1984).

The Centre for Research on the Epidemiology of Disasters (CRED) defines a disaster as an event that must meet at least one of the following criteria:

1. More than ten casualties
2. More than ten people have been affected
3. The state has declared an emergency
4. International assistance has been called for

1.1.1 Hazards

Makoka and Kaplan (2005) describe a hazard as a harmful or destructive physical event, a phenomenon, or even a human activity that has a destructive potential leading to injury or even loss of life, social and/or economic disruption, or even deceleration of environmental phenomena. The UN International Strategy for Disaster Reduction (UNISDR) describes a hazard as a natural occurrence that could have adverse ramifications on the economy and society, as well as flora and fauna. The origins of the word "hazard" can be traced back to a word from old French, "hasard", and to the word "az-zahr" from Arabic which means "chance" or "luck".

Shi (2019) further explains the interplay between hazards and vulnerabilities as hazards are external factors that impact the community or are elements associated with several risks, whereas vulnerabilities are the internal factors that influence the transformation of hazards into disasters. In another aphorism, vulnerabilities are the determining factor when calculating the impact of a hazard on society or community. Hazards can be single, sequential—that is, one after the other or one leading to the other—or in a combined form in terms of the effects and their origin. Each hazard is characterized

by its probability, frequency, magnitude or intensity and location (United Nations, 2021).

1.1.2 Disaster

The word disaster can be traced back to its origins in the French word "desastre", which is formed by combining two words—"des", which means bad, and "aster", which means star; hence, the terms combined means "a bad or evil star". According to the Oxford dictionary, it is an abrupt accident or a natural catastrophe that results in significant property damage or loss of life. A disaster is an event (single event) or succession of events (in sequence one after the other, or even combined), which create an impact in the form of casualties, loss of property and physical infrastructure, damage to the environment, and/or impairment of essential services and livelihood. All of the mentioned impacts are on a scale that is beyond what is considered normal and what can be endured by the affected community.

A disaster can also be described as a catastrophic condition during and after which the day-to-day pattern of life and the normal ecosystem of a place have been disrupted. For these conditions, out-of-the-ordinary mediation and interventions are needed to preserve lives, as well as to save and protect the pertaining environment. A disaster may be defined as any serious occurrence which could disrupt the normal conditions for the existence of life and cause an unprecedented level of suffering that exceeds the potential of adjustments that the affected community could undertake. It is people who are affected the most, which means that without people, there is no such thing as a disaster (World Health Organization, 2002).

The UN defines the term disaster as "the occurrence of a sudden or a major misfortune which disrupts the basic fabric of living conditions and life, and the normal functioning of the society or the community that has been the victim of it" (Basu and Svarimuthu, 2018: 343). According to the International Federation of Red Cross and Red Crescent Societies (IFRC), a disaster is an abrupt, catastrophic event that gravely impairs a community's or society's ability to go about its daily business and results in losses to people, property, material, economy, infrastructure, and the environment that far outweigh those capacities to return to the normal conditions using just its reservoir of resources, funds, or anything else (IFRC, 2021).

A disaster can also be defined as a natural or human-caused accident or negligence, catastrophe, mishap, calamity, or grave occurrence in any area. It results in substantial loss of life, human suffering, or damage to and destruction of property, or damage to—or degradation of—the environment. It is of such a serious nature or an unprecedented magnitude that is beyond the survival capacity of the people who are present in the affected area (Government of India, 2005).

The disaster risk can be calculated by the formula:

$$\text{Disaster Risk} = \text{Hazard} \times \text{Vulnerability} \div \text{Capacity}$$

1.1.3 Difference Between a Hazard and a Disaster

The phenomenon of a disaster depends upon the hazard; as such, there are no such events to be known as natural disasters. A hazard is an event that has the potential to bring about a major loss of human life and immensely damage physical infrastructure and property, including the environment; whereas a disaster is a phenomenon succeeding

a hazard and is a consequence of the impact that the hazard has on the society, environment, economy, etc., at variable degrees and magnitudes. The effect that a disaster has on a community is determined by the extent to which a community is vulnerable to a particular hazard (UNISDR, 2002). This vulnerability does not naturally exist, but rather is the outcome of constantly changing social, economic, political, cultural, physical, and psychological variables. These variables shape the daily lives of people and thus shape the environments in which the community lives.

1.2 Classification of Hazards and Disasters

Several kinds of hazards affect human society. However, from a broader perspective, hazards can be divided into two typologies. These include natural hazards which can be defined as hazards caused by natural factors and human-caused hazards which can be defined as hazards caused by human intervention and anthropogenic factors. Natural hazards are dwindling, while human-caused hazards are increasing. The common characteristics of hazards previously discussed allow us to consciously categorize them into overarching categories. There is a variety of classifications being used today internationally. "Living with Risk: A Global Review of Disaster Reduction Initiatives" (UNISDR, 2002: 44) has categorized hazards into three different typologies as explained in the following subsections (Niekerk, 2011).

1.2.1 Natural Hazards

Despite the term including the word "natural", a natural hazard is significantly influenced by the participation of humans. Typically, a physical event like a volcanic eruption that does not affect human beings at all would just be characterized as a natural phenomenon, and thus it would not be called a natural hazard. But, when the said natural phenomenon occurs in an area that is populated by human beings, it would be recognized as a hazardous occurrence in nature. Thus, when a hazardous phenomenon or event causes a grave impact in the form of a large number of fatalities, loss of belongings, and damage to physical infrastructure, it would turn into a natural hazard.

Hazards that have their origins due to natural phenomena—which could be in the form of meteorological, geological, or even biological phenomena—would be termed natural hazards (Table 1.1). Some examples of natural hazards can be earthquakes, tsunamis, cyclones, and volcanic eruptions, as these hazards purely originate from natural phenomena. On the other hand, instances of fires, landslides, droughts, and floods can be classified as socio-natural hazards since the cause of these hazards can be traced to natural as well as human-caused phenomena. For example, flooding—a hazard, by all means—may be caused by natural phenomena such as heavy rains, landslides, or even the blocking of natural or human-caused water drains of water by human waste byproducts (Table 1.2).

1.2.2 Anthropogenic Hazards

Anthropogenic hazards, on the other hand, are hazards that are usually caused by human action or even inaction. Often, these are called technological or human-caused hazards. These types of hazards are associated with industrial facilities such as energy generation facilities. They also include hazardous events such as explosions, wars or civil strife, leakage of toxic waste, pollution, dam failure, etc. Many of these events occur frequently

Table 1.1 Classification of Hazards

Typology of Hazards	*Characteristics of the Hazard*	
1. Geological hazards	1. Landslide	4. Earthquake
	2. Mine fire	5. Dam failure
	3. Volcanic eruption	6. Tsunami
2. Environmental hazards	1. Environmental pollution	3. Desertification
	2. Deforestation	4. Infection from pests
3. Hydrometeorological hazards	1. Hailstorm	6. Avalanches
	2. Landslide	7. Drought
	3. Cloudburst	8. Heat or cold wave
	4. Floods	9. Tornado
	5. Tropical cyclone or hurricane	10. Sea erosion landslide
		11. Permafrost
4. Technological hazards	1. Chemical disasters	7. Oil spill, fire
	2. Industrial disasters	8. Nuclear hazard, radioactivity
	3. Boat, road, train accident, air crash	9. Collapse of buildings
		10. Electrical hazards
	4. Rural or urban fires	11. Festival-related disasters
	5. Bomb blasts	12. Flooding of mines
	6. Forest fires	
5. Biological hazards	1. Human epidemics (COVID-19, SARS, MERS, etc.)	4. Food poisoning
		5. Mass destruction weapons
	2. Animal epidemics	
	3. Infestation of pests	

Source: Compiled based on Niekerk (2011)

throughout the lifetime of the industry, while others take place occasionally. These kinds of disasters are increasing nowadays since human intervention started. The nuclear attack by the United States on Japan during the Second World War is a suitable example of a technological hazard.

1.2.3 Environmental Hazards

These types of hazards are instigated by human behavior and activities (which often occur as a combination with natural hazards) that harm the natural reservoir or adversely affect the natural processes of flora and fauna. Potential effects are varied, and these effects may increase the vulnerability of the community, the intensity of the hazard, and the frequency with which the hazard occurs. A few of the hazards that are the absolute instances of environmental hazards are deforestation, veld fires, land degradation, loss of biodiversity, desertification, pollution (of land, water, and air), climate change, global warming, ozone depletion, sea-level rise, etc.

1.3 Basis of Hazards Upon Occurrence of Onset

Broadly speaking, there is a distinction between rapid-onset and slow-onset hazards, as various hazards are different in terms of their rate of onset (Nelson, 2018). Even a particular hazard like flooding can have both a rapid and slow onset. Natural hazards may also be divided into rapid-onset and slow-onset hazards.

Table 1.2 Characteristics of Various Hazards

Category of Hazard	*Class of Hazard*	*Code*	*Particulars*	*Element of Hazard*
1. Geophysical hazards	Tsunami	TS	A significant volume of water gets displaced, which generates a series of waves that are characteristic of low amplitudes and significantly larger wavelengths.	When TS waves approach the shallower water near the coast, and the amplitude of these waves increases through the concept of wave shoaling.
	Earthquake	EQ	Stored elastic energy is released suddenly between the plates in the lithosphere region, which is caused by its abrupt movement or fracturing along zones of pre-existing geological weakness. It results in the generation of seismic waves.	Shaking of the ground, a rupture in the ground, and liquefaction.
	Landslide	LA	It is commonly referred to as landslips which is a large-scale movement of debris, rock, or earth down a slope. It may take place quickly or more gradually over an extended period of time.	Rockfall, translational and rotational slide, soil creep, lahar, and debris flow.
	Volcanic eruption	VO	There is the movement of magma in the subterranean regions of Earth, resulting in its eruption and ejection from volcanic systems together with gases, ash, and associated tephra due to the pressure confining it and the superheated gases and steam.	Pyroclastic and lava flows, ash and tephra ejection, gas and aerosol emissions.
	Snow avalanche	AV	There is a displacement of all the surface materials, which are predominantly ice and snow, down a slope under the influence of gravitational forces.	AVs can start impulsively, as a result of causes like increasing precipitation or decreasing accumulation of snow, or by outside forces like earthquakes, animals, and people.
2. Hydrological hazards	Drought	DR	A prolonged period accompanied by lower-than-expected precipitation results in a severe hydrological imbalance or results in the removal of water—which once it exists persists through poor agricultural practice or water diversion.	Agricultural drought, hydrological drought, and meteorological drought.
	Flood	FL	The overwhelming abundance of water on a typically dry area of land.	Coastal flooding, flash flood, storm surge, rural ponding, urban flood, fluvial flood, glacial lake bursts, etc.
3. Hazards caused by shallow Earth processes	Ground heaving	GH	Upward vertical movement of the surface of the ground may happen suddenly or gradually.	Expansion (swelling) of soils and rocks, and tectonic uplift.
	Regional subsidence	RS	Downward vertical movement of the surface of the ground over a regional spatial extent may happen suddenly or gradually.	Tectonic subsidence.
	Soil (local) subsidence	SS	Downward vertical movement of the surface of the ground over a localized spatial extent may happen suddenly or gradually.	Natural consolidation and settlement, soil shrinkage.
	Ground collapse	GC	Downward vertical movement of the ground surface into the ground, which happens rapidly.	Piping, metastable soils, karst, and evaporate collapses.

Category of Hazard	*Class of Hazard*	*Code*	*Particulars*	*Element of Hazard*
4. Atmospheric hazards	Hailstorm	HA	Strong updrafts occur within a convection storm whereby there is an ample amount of supply of supercooled water droplets due to a severe deviation in the atmospheric system from its normal state. This results in heavy precipitation in the form of hailstones, provided they have gained sufficient mass to leave the said atmospheric system.	It is a solid form of precipitation which is made up of hailstones, which are ice balls or other irregularly shaped chunks. The growth of hailstones is significantly slowed down when it is cold outside.
	Snowstorm	SN	Heavy precipitation in the form of snow is due to a severe deviation in the atmospheric system from its regular state.	Water droplets freeze on a solid surface.
	Storm	ST	Heavy precipitation and winds of violent nature formed due to a severe deviation of the atmospheric system from its normal state.	A tropical cyclone, hurricane, typhoon, or mid-latitude storm.
	Tornado	TO	It is a violently rotating column of air (normally) that is in contact with the Earth's surface and is formed from a cumulonimbus cloud.	It is a short column of air that emerges from a thunderstorm and spins violently until it reaches the ground.
	Extreme temperatures (cold)	ET (C)	A prolonged period of temperatures that are below the normal average for the designated period (regional, local, or global; for a short or long term).	Climatic change, cold waves.
	Extreme temperatures (hot)	ET (H)	A prolonged period of temperatures that are above the normal average for the designated period (regional, local, or global; for a short or long term).	Climatic change, heat waves.
	Lightning	LN	The discharge of static electricity in the atmosphere which occurs when the resistance between areas of positive and negative charge is overcome (the resistance is of the intervening air).	It develops during a thunderstorm as a result of the buildup of positive and negative charges.
5. Biophysical	Wildfires	WF	An uncontrolled fire fueled by natural vegetation.	Wildfires are frequently brought on by human activity or a natural occurrence.
6. Space/celestial	Geomagnetic storms	GS	These occur when there is a severe deviation in the magnetosphere of the Earth caused by the changes in the weather of space, such as changes caused due to the intensity of solar winds.	It is a significant disturbance of the earth's magnetosphere.
	Impact events	IM	The impact on the surface of the Earth by a celestial body.	Meteorite, asteroid.

Source: Gill and Malamud (2014)

1.3.1 Hazards With a Slow Onset

Slow-onset hazards can be easily predicted but these hazards can have a high impact on the environment. These types of hazards are usually preceded by several early warnings in the form of indicators or signs. Early warning systems that function to predict the weather play a crucial role in the reduction of risk, mitigation of damage from such possible disasters, and preparation for their aftermath. Representative cases of such slow-onset hazards are environmental degradation or pollution, droughts, desertification, tropical cyclones, landslides due to heavy rains, deforestation, insect infestations, and epidemics, which usually take years to develop. Despite being very insightful, early warning signs of these disasters often tend to be ignored until it is too late to take any kind of step or action to reduce the risk of or prevent severe damage from these disasters.

1.3.2 Hazards With a Rapid Onset

As the name of the classification indicates, hazards with a rapid or sudden onset occur with very little warning (sometimes even without any warning). Even though these hazards are mostly unpredictable, much damage could be mitigated from the said disasters if there is preparedness and proper planning has been done. Instances of these hazards are volcanic eruptions, earthquakes, floods, flash floods, landslides, tsunamis (tidal waves), severe thunderstorms, lightning, and pest infestations, which give little warning and occur rapidly.

1.4 Types of Disaster

A disaster is a severe event that causes mass disruption over a short or long interval of time. It underlies widespread loss of human lives, infrastructure damage, economic crises, and environmental damage which exceed the community's or society's ability to return to normal conditions using just its reservoir of resources, funds, or anything else. Disasters can be classified under the following two categories.

1.4.1 Natural Disasters

Natural disasters are macro-scale events of geological or meteorological nature that have the potential to turn into a disaster and cause loss of life and damage to infrastructure. These types of disasters include:

1. Earthquakes
2. Tsunamis
3. Cyclones
4. Landslides and mudflow
5. Floods—cloud bursts, dam failures, and dam bursts
6. Volcanoes
7. Avalanches
8. Biological (human/animal epidemics or pandemics like COVID-19)

Some instances of these kinds of disasters are briefly mentioned. In 2012, Hurricane Sandy was a large storm that hit the USA's east coast. It was accompanied by violent gusts and storm surges that caused major flooding all along the east coast. It left people

in the affected states without any power and more than 100 people were reported dead, while tens of thousands of people were injured and displaced. Apart from this, the Earthquake and Tsunami of Japan (2012), Cyclone Nargis in Myanmar (2008), Kashmir Floods (2014), Uttarakhand Flash Floods (2013), Bihar Floods (2007), The Indian Ocean Tsunami (2004), Gujarat Earthquake (2001), Super Cyclone of Odisha (1999) and the Great Bengal Famine of the 1770s, are some of the key instances of natural disasters.

Apart from the above, very interesting coverage of biological disasters, which comprise human and animal epidemics is crucial to discuss here. A recent example of such a biological disaster that has affected the world on a varying scale, was the Coronavirus Disease-19 (COVID-19). Occasionally, this virus is known as the Wuhan coronavirus and sometimes as the Novel Coronavirus-19 (2019-nCoV). It is believed to have originated in Wuhan, a city in China on 26 December 2019, and has made us all think about how extensive the impact of a disaster can be. As of 12 February 2021, nearly 107,423,526 people were affected by this virus worldwide, which means that 1,376.11 people per 100,000 people were affected globally. Moreover, in the same period, the virus killed nearly 23,60,280 people globally, which accounts for 30.23 deaths per 100,000 people (WHO, 2021). The detailed description and its country-wise impacts have been covered in Chapter 2 of this book. The classification and types of natural disasters are presented in Tables 1.3 & 1.4.

1.4.2 Human-Caused Disasters

Human-caused disasters are those kinds of events that are proliferated by human beings and usually occur in human settlements or close to them. These hazards may be the result of deliberate or negligent human actions or inactions, but their impact can be equally as terrifying. These types of disasters include:

1. Riots
2. Nuclear, chemical, and biological disasters
3. Industrial accidents
4. Wars
5. Sabotage
6. Air, road, and rail accidents

Here, a few examples of such disasters are discussed. On 26 April 1986, in Chornobyl, present-day Ukraine, there was an accident that caused a fire in a nuclear reactor. This flung huge amounts of radioactive material into the atmosphere from the nuclear plant, eventually leading to the entire population in the city being evacuated. Apart from this, in the period between 1942 and 1953, 21,000 tons of toxic chemical waste were disposed of in a canal named Love Canal in New York, United States by Hooker Chemical Company. Later, reports came in that the chemicals that had been disposed of in the canal had leaked into the homes of people, yards, and school playgrounds and created toxic puddles after years of heavy rains. Another such human-caused disaster was when a dioxin poison cloud spread from a chemical plant in Meda, Italy in 1976. Other examples of human-caused disasters include the Bhopal gas tragedy of 1984, which is called the worst industrial accident; the time when yellow smoke rose from an exploded chemical plant in Jilin, China; the Gulf War oil spill, which is one of the largest oil spills