

The background of the book cover is a photograph of a sunset or sunrise over a body of water. The sun is a bright white circle in the upper center, surrounded by a large, glowing orange-red halo. The sky is a deep, dark red. The water in the foreground is dark, with numerous small, shimmering reflections of the sun's light.

BIMAL KANTI PAUL
HARUN RASHID

CLIMATIC HAZARDS IN COASTAL BANGLADESH

NON-STRUCTURAL AND STRUCTURAL SOLUTIONS





CLIMATIC HAZARDS IN COASTAL BANGLADESH

Non-Structural and Structural Solutions

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CLIMATIC HAZARDS IN COASTAL BANGLADESH

DEDICATION

The risk of cyclone deaths in coastal Bangladesh due to storm surge inundation “intensifies as global warming causes the sea to rise... This means [says Dick Warrick, at East Anglia University’s climate research unit] that future tidal waves will come from a higher sea level and will submerge more land” (M. Simon, *The Guardian Weekly*, 12 May 1991).

This book is dedicated to all past and future climate change victims of coastal Bangladesh.

AUTHOR BIOGRAPHY

Bimal Kanti Paul, PhD (Kent State University, Ohio, USA) is a Professor of Geography at Kansas State University, Manhattan, KS, USA, where he has been teaching for last 26 years. He specializes in geography of environmental hazards and disasters, health/medical geography, population geography, and quantitative analysis in geography. Dr. Paul has a very impressive publication record—to date he has published 91 papers in nearly 40 referred journals, two books (one co-author with Harun Rashid), 25 book chapters, 17 book reviews, and 32 other papers. Most of these publications are the outcomes of externally funded research grants, including three from the National Science Foundation. In four different times, Dr. Paul received fellowships from the American Institute of Bangladesh Studies. He was immediate past editor of the *Geographical Review*, a publication of the American Geographical Society. Prior to that, he was book review editor of *The Professional Geographer*, a quarterly journal of the American Association of Geographers (AAG). He is currently a member of the editorial boards of several professional journals, including *The AAG Review of Books*. He also served as a member of the Editorial Board of several professional social science journals.

Harun Rashid, PhD (University of Saskatchewan, Canada) is an Emeritus Professor at the University of Wisconsin-La Crosse, USA. Earlier, he taught at the University of Wisconsin-La Crosse (2004–2009); Lakehead University, Canada (1975–2004); University of Benin, Nigeria (1981–1982); and University of Dhaka, Bangladesh (1965–1969). Dr. Rashid has published peer-reviewed journal articles and book chapters on floodplain management and urban floods in Bangladesh, Canada, USA, and Nigeria. His other peer-reviewed articles include such diverse environmental topics as shoreline management on the Great Lakes, morphologic effects of dams and flood control channels (channelization projects), remedial action plans for pollution alleviation in the Great Lakes, choice modeling in water resources management, and media discourse on floods and climate change. He is the co-author of two books on climate change in Bangladesh (Rashid and Paul 2014;

Paul and Rashid 2017). Dr. Rashid is a member of the editorial board of four international journals: *Disasters*, *International Journal of Disaster Risk Reduction* (IJDRR), *Environmental Management*, and *The Arab World Geographer*. He had also a keen interest in research administration and served as the Acting Associate Vice President Research at Lakehead University for two and half years (2002–2004).

PREFACE

For more than last three decades, we have conducted and published many studies on environmental issues and natural hazards and disasters in Bangladesh, Canada, Nepal, Nigeria, and the United States. We conducted research on different types of disasters, including river and flash floods, tornadoes, cyclones/hurricanes, blizzards, earthquakes, tsunamis, droughts, and forest fires. We dealt with a wide range of issues associated with these disasters, such as hazard preparedness, public and household response, individual perception, awareness and interpretation of hazards, compliance with hazard warnings, evacuation behaviors, emergency relief, recovery and rebuilding efforts, disaster-induced mortality and morbidity, disaster damage and impacts, and individual and household coping mechanisms.

Disasters can strike any place. Therefore, our initial interest was in the place affected by such extreme events. Our focus started to shift to a specific place, i.e., Bangladesh, since the early 2000s. By that time interests in global warming and climate change, which were initially confined primarily among climate specialists and scientists, had received significant attention of policy makers, politicians, mass media, and many concerned groups, such as nongovernmental organizations. As our ancestral homeland is in Bangladesh, naturally we became very much concerned about potential impacts of global warming—induced sea level rise, which is likely to inundate large parts of coastal Bangladesh, potentially displacing millions of people from their homes. Since the publication of the first report of the Intergovernmental Panel on Climate Change, estimates of potential loss of land due to sea level rise in coastal Bangladesh have been revised several times. According to the most conservative estimates, about one-fifth of the land area of the country would be lost due to a sea level rise of 3 feet (1 m) by the middle of this century with a corresponding displacement of at least 15 million people. Some other estimates projected much larger-scale population displacement from Bangladesh.

Our concerns about climate change impacts on the environment and livelihoods of the people of Bangladesh were reflected in a co-authored book entitled *Climate Change in Bangladesh: Confronting Impending Disasters*, which was published in 2014 by Lexington Books. We devoted a significant part of that book to sea level rise and its implications for Bangladesh. Although the book was on the entire country, it had a significant section

on coastal Bangladesh. The current book may be considered as a sequel to this publication, thanks mainly to Kenneth P. McCombs, Senior Acquisitions Editor of Science and Technology Books, Elsevier, who encouraged us to consider a more in-depth analysis of coastal hazards in Bangladesh. We are heavily indebted to him for prodding us to this project. He followed up the project at every stage of its progress with a professional zeal and inspiration. We missed several deadlines, but he never lost his confidence in us. His constructive suggestions and efficient handling of every aspect of the manuscript have helped us in completing this important task. We are also grateful to the team at Elsevier, particularly Jardim Peter, and Mohana Natarajan for their professionalism and patience.

Although this book is about climatic hazards in coastal Bangladesh, in each chapter of the book we have provided a global context before turning into the area of our interest. In writing this book, we used materials from numerous sources. However, we have drawn heavily from our own publications on natural/climatic disasters in Bangladesh, which span a period of at least three decades. After introducing climate change challenges for Bangladesh and the coastal region, we have covered in detail four climatic hazards that pose the greatest threats to human lives in coastal Bangladesh. Land use changes in the coastal region are then presented along with programs so far implemented to properly and efficiently manage the coastal zone of the country. The next two chapters are on nonstructural and structural adaptation to sea level rise. The concluding chapter provides a summary of the main findings and recommendations for confronting some of the main challenges of coastal Bangladesh.

For the successful completion of this project we have benefited from numerous contributions of many of our colleagues, friends, and students. Our colleagues both at Kansas State University and University of Wisconsin—La Crosse always provided support and encouragements in our academic endeavors, including writing of this book. We frequently consulted with them about our writings, and their suggestions and constructive criticisms helped us tremendously. We are also grateful to several international colleagues and friends who gave us permission to reproduce some of the photographs from their personal collections. Dr. Emdad Haque (Professor, NRI, University of Manitoba, Canada) provided some of the rare historical pictures of damages from the 1991 Cyclone Gorky. The credit for the picture on shrimp polders (*ghers*) goes to Dr. Salim Momtaz (Associate Professor, University of New Castle, Australia). Two pictures in chapter 2 were provided by Dr. M. Khaledur Rahman (Post-Doctoral

Fellow, Center for Sustainability, Saint Louis University, St. Louis, MO, USA), whereas pictures of cyclone shelters were provided by MD Nawfel Huda and Khairul Matin (consultants). We acknowledge Dr. Masud Karim (engineering consultant) for pictures on the Sundarbans mangrove forest. We are grateful to Dr. Mohammad Zaman (an international consultant for the World Bank, ADB, Government of Bangladesh and others), who delivered some of the above pictures to us through his contact with Dr. Karim and two of his colleagues (i.e., Huda and Matin). We would also like to take this opportunity to pay homage to two of our inspiring teachers, mentors, and esteemed colleagues, the late Professor Aminul Islam and the late Professor Moniruzzaman Miah, who inspired us in geographical studies on natural hazards and disasters in Bangladesh.

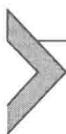
Finally, we are deeply indebted to our family members, particularly to Mohsina Rashid and Anjali Paul, both of whom have been an enduring source of inspiration and have sacrificed countless hours of family life for the successful completion of this book project. Our children (Anjana Paul, Archana Paul, Rahul Deb Paul, Moona Rashid-Tyres, Zaid Rashid, and son-in-law Steve Tyres) and grandchildren (Shaun Tyres and Raiyah Tyres) have been waiting for the completion of this project. Their love, encouragement, and support over the years and particularly during the time we were busy writing this book have been a source of constant encouragement and inspiration.

Bimal Kanti Paul, Manhattan, Kansas, USA
Harun Rashid, Maple Ridge (Greater Vancouver), BC, Canada
July 2016

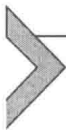
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Introduction



CLIMATE CHANGE AS A GLOBAL PROBLEM

Who Are Polluting Our Atmosphere?

Climate change has emerged as a pervasive environmental problem for the entire world. Increasing concentration of greenhouse gases in the atmosphere is the root cause of this problem. Since most of the countries of the world have contributed more or less certain amounts of greenhouse gases into the atmosphere it can be argued that climate change is a collective global responsibility. Yet, data in Table 1.1 show that only a handful of industrial nations have emitted disproportionate amounts of greenhouse gases into the global atmosphere. This is the global context for opening this chapter and this book with a provocative question “who are polluting our atmosphere?”

Our question is based on an assumption (or more like an assertion) that the atmosphere is a global common property (called “a global commons”) that is shared by all citizens of the world. This assumption is rooted in one of the basic physical characteristics of the atmosphere that it is an open system that exchanges energy and matter freely throughout the entire global atmosphere. The exchange of energy takes place through different forms of radiation. Solar radiation is the most basic form of energy for the atmosphere. Earth radiation (also called thermal infrared radiation) is another form of energy that is radiated by the earth surface into the atmosphere. Matters in the atmosphere include gas molecules (such as nitrogen, oxygen, carbon dioxide, ozone, and others), water vapor, dust particles, aerosols, and different types of particles from volcanic eruptions. Differences in air temperature from one place to another result in differences in air pressure which generates winds. At the global scale, a number of major wind systems called prevailing winds, such as the southeasterlies, the northeasterlies, southwesterlies, northwesterlies, and polar easterlies, transport both energy and matter across the latitudes. Thus, colder winds from the polar region are transported to tropical areas, whereas warmer tropical winds are carried to higher latitudes. Obviously, these exchanges of energy and matter do not follow any political boundary. Thus, warmer air temperatures attributable to

Table 1.1 Geography of Carbon Dioxide Emissions in 1990, 2000, and 2010

| 1990 Total Global Emissions: 22 Gt^a | 2000 Total Global Emissions: 25 Gt | 2010 Total Global Emissions: 33 Gt |
|---|---|--|
| USA (22.62% of global total) ^b | USA (23.13% of global total) | China (26.36% of global total) |
| China (11.21) | China (13.88) | USA (16.37) |
| Russia (11.06) | Russia (6.56) | India (5.38) |
| Japan (5.27) | Japan (5.03) | Russia (5.18) |
| Germany (4.63) | India (4.18) | Japan (3.75) |
| Ukraine (3.49) | Germany (3.42) | Germany (2.49) |
| India (2.99) | Canada (2.17) | South Korea (1.79) |
| UK (2.67) | UK (2.15) | Canada (1.68) |
| Canada (2.03) | Italy (1.81) | UK (1.54) |
| Italy (1.93) | South Korea (1.77) | Mexico (1.39) |
| Top 10 countries: 68% | Top 10 countries: 64% | Top 10 countries: 66% |
| France (1.78) | France (1.61) | Indonesia (1.37) |
| Poland (1.41) | Mexico (1.49) | Brazil (1.32) |
| Mexico (1.41) | Australia (1.41) | Australia (1.31) |
| Australia (1.24) | Ukraine (1.39) | Saudi Arabia (1.29) |
| South Africa (1.22) | Brazil (1.36) | Italy (1.27) |
| Kazakhstan (1.16) | Iran (1.35) | France (1.19) |
| South Korea (1.14) | South Africa (1.22) | Iran (1.17) |
| Spain (1.03) | Spain (1.21) | Poland (1.01) |
| Brazil (0.99) | Indonesia (1.16) | South Africa (1.00) |
| Iran (0.93) | Poland (1.14) | Ukraine (0.92) |
| Top 20 countries: 80% | Top 20 countries: 77% | Top 20 countries: 78% |
| Contributions by remaining 167 countries: 20% (each country contributed between 0.01% and 0.9%) | Contributions by remaining 167 countries: 23% (each country contributed between 0.01% and 0.9%) | Contributions by remaining 167 countries: 22% (each country contributed between 0.01% and 0.9%) ^c |

^aSee endnote 2 for an explanation of the short form Gt.

^bCountries in bold indicate Annex I countries (see endnote 1).

^cIn 2010, Bangladesh contributed 0.35% of global total greenhouse gas emissions.

Prepared by authors based on original data from EDGAR tables Olivier, J.G.L., Janssens-Maenhout, G., Muntean, M., Peters, J.H.A.W., 2014. Trends in Global CO₂ Emissions — 2014 Report. PBL Publications, The Hague.