Handbook of Drought and Water Scarcity
Management of Drought and Water Scarcity
Saeid Eslamian, Faezeh Eslamian

Capacity Building and Drought Management

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Shafi Noor Islam, Sandra Reinstädtler, Albrecht Gnauck
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Abstract  Drought is a new challenge presenting natural calamities to modern civilized societies. Natural resources are the fundamental treasures of human life and are also the driving force for sustainable development and human civilization. Geographically, the surface land of the world is divided due to climatic and tectonic conditions. Human civilization, urban development, and agricultural cropping patterns are totally dependent on naval communication and water availability. The changing behavior or changing nature of climate and the scarcity of water and increase in temperature is creating annual droughts in different parts of the world. Soil formation and fertility development depend on the water supply and quality of surface and ground water storage. Due to climate change impacts such as droughts, cyclones, floods, and other natural calamities. It has been estimated that the similar characteristics appeared in the tropical and subtropical regions. It has also been indicated that by 2025, 1.8 billion people will be living in regions with absolute water scarcity and about two out of three people in the world could be living under considerations of water and natural resource stress. Therefore the sustainable use of natural resources including water, soil, forest, air, oil, gas, and petroleum in the mining sectors should be considered within terms of drought and other relevant environmental calamities. In such a crucial environmental situation, strategic drought mitigation policies and technological awareness is necessary to protect nature through mitigation and adaptation to drought and to reduce vulnerabilities to other natural calamities. The approaches are probable factors for drought mitigation and natural resources management in the vulnerable areas of the world could be considered as a priority basis environmental issue. Primary evaluation
indicates that an increased utilization of natural resources could be a threat to future food security and the sustainability of natural resources. The engineering technology setup of natural resources practices guideline is needed within the present drought and environmentally harsh conditions. The innovation of a climate-smart approach and a drought management plan could be practiced globally toward protecting of natural resources from drought damages through capacity buildings.

3.1 Introduction

The world population has gradually increased from 2 to 20 million, when agriculture was first established about 12 million years ago, today the population size is 7.2 billion in 2013. The present figure will reach 9.6 billion by 2050 and 11 billion by 2100 [80]. Consequently, global food production will have to be increased by 50% to meet the demand of the present population growth. Global natural resources play a potential role in food production, economic development, and the balance of natural ecology [23,80]. Particular interest has been shown to different categories of natural resources around the world with regard to the extent of their uniqueness and attributes [54]. This includes forest, wetlands, soil, vegetation, fisheries, livestock, water bodies, habitats, and wind and mineral resources. These resources are found in every continent except Antarctica and in very rough climates from the tropics to the tundra. The forest is the most important natural resources are frequently uses in different regions of the world. It is estimated that 31% of the world’s surface area represents forest resources [23]. The most critical areas are the developing countries in Asia, Africa, and Latin America, where huge volumes of people are dependent on forest resources. A total of 750,000 km² of wetlands has been registered with the Convention on Wetlands of International Importance as of 2000 [54].

Forest and water resources in different regions of the world have great importance for a country’s economic, industrial, ecological, socioeconomic, and cultural context [35] since they contain very rich components in the biodiversity of all valuable ecosystems [38,48,60]. The forest and wetland resources of developing countries, such as in Asia, Latin America, and African countries, have suffered drastically from the impact on natural resources of a growing human population and anthropogenic activities, climate change, and other natural calamities. Furthermore, natural resources are recognized as a factor in biodiversity conservation and in rural and urban socioeconomic improvement [3,60].

Drought is a natural disaster for society contrast climate change impacts as well as drought, cyclones, floods and other natural calamities are getting most critical environmental issues for analysis and discussion. Modern civilization, agricultural production, and technological development is totally dependent on green nature, natural resources, and water availability. All types of management are dependent on the proper planning of the sustainable use of natural resources and the establishment of good governance all over the world. This would be the right option to protect and conserve natural resources from the calamity of drought and other natural disasters [22].

In South Asia, in the Ganges-Brahmaputra-Meghna floodplain alone, approximately 2.1 million ha of wetlands have been lost due to flood control, drainage, and irrigation development [46]; therefore, wetlands are facing serious challenges from environmental changes and anthropogenic impacts [3,59,72]. Bangladesh is a land of wetlands; it lies in the eastern part of the Bengal Basin, one of the largest river flood plains in the world. The people of Bangladesh have long depended on the basin’s three formidable rivers, the Padma (Ganges), the Jamuna (Brahmaputra), and the Meghna, as well as their numerous smaller tributaries and distributaries, for fresh water, transportation, fish, and for the floods that deposit fertile silt on their farmland each year [74]. In Bangladesh, where inland water bodies constitute nearly 50% of the total land area, wetlands are critical to economic development and environmental improvement. The total area of wetlands in Bangladesh is estimated to be 70,000–80,000 km² [5,46]. This includes rivers, estuaries, mangrove swamps, marshes (haor), oxbow lakes (baor), natural water shade (beels), water storage reservoirs, fish ponds, and some other lands [28,30,40,45].

The major roles of a wetland are nutrient retention/removal, support for food chains, fisheries production, habitat for wildlife, recreation, natural heritage values, biomass production, water transport, biodiversity
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presentation, and micro-climate stabilization \cite{28,41}. All these environmental sectors are now affected by climate change as well as drought calamities in different parts of the world. A comprehensive analysis of the various issues leads to natural resources degradation in different parts of the world, such as in Asia, Africa, Latin America, Europe, and Australia, and the very specific case location in Bangladesh. This comparative analysis utilized applied research findings on the natural resources in Bangladesh and some other examples. The smart use of natural resources can solve ecosystem problems on global surface areas and ensure food security and the sustainability of community livelihoods in different climatic regions through capacity building. Capacity building is the process of gaining technical, managerial, and instrumental knowledge and insight into the relations between socioeconomic structures, cultural standards, and the values of the societies concerned. It aims to increase the flexibility of institutions and society to adapt to the changing circumstances. Specifically, capacity building encompasses the countries’ human, scientific, technological, organizational, institutional, and resource capabilities. Throughout this chapter present drought mitigation and adaptation possibilities will be investigated in the Bangladesh case as well as in other cases.

### 3.2 Aims and Objectives

The objective of this chapter is to understand the characteristics of natural drought calamities in general and the drought distribution pattern in the world and the interlinked drought impacts. We will also investigate drought impacts on environmental issues so as to promote the sustainable management of natural resources in the global context. Capacity building is one of the key components for those interested in fostering the effective implementation of policies regarding wetlands and world forest protection in the context of sustainable natural resource management. The following specific objectives of drought management through capacity buildings are as follows:

- A special investigation limited to the Bangladesh case with a comparison to other countries in a global context
- To measure the protective scenarios of water shade and wetlands, soil conditions, forest ecosystems, and their biodiversity
- To measure the major threats of drought and to provide guidance for the wise use of natural resources toward mitigating drought vulnerabilities
- To recommend capacity building for the future development of natural resources from the effects of drought in the global context owing to climate change impacts, especially in developing countries

### 3.3 Concept and Scientific Understanding of Drought

Drought refers to a considerable and prolonged lack of rainfall over a wide area that significantly affects agriculture, domestic water supply, and water dependent economic activities, which may lead to famine. Scientifically drought is defined by the nonavailability of rainfall, leading to a decrease in the base flow and surface flow of water bodies and the depletion of soil moisture \cite{57}. Drought is a temporary and recurring meteorological event which originates from the lack of precipitation over an extended period of time \cite{55} and is a normal part of climate often described as a natural hazard. Drought by itself does not trigger an emergency, but a long lasting drought becomes an emergency due to its severe impact on agriculture and the lives of the drought victims. It is directly and/or indirectly related to life and livelihoods, water quality, air pollution, and food security, which are the basic requirements of any form of life \cite{1,10–12,18}. Drought is primarily considered as an agricultural phenomenon that refers to the conditions where plants are responsive to certain levels of moisture stress that affect both vegetable growth and the yield of crops. It occurs when the supply of moisture stored in the soil is insufficient to meet the optimum need of a particular type of crop \cite{21}.

As a consequence of the usual hydro-meteorological variability, drought occurs in the pre-monsoon season when the potential vapor transpiration (PET) is higher than the available moisture due to uncertainty
in rainfall, while in the post-monsoon season it is due to a sudden increase in temperature coupled with the nonavailability of rainfall that causes a sharp rise in PET. The offset of drought is slow as it is influenced by climatic fluctuations over an extended period of time. The affected area is widespread. Drought causes are seen in soil degradation, loss of crops, loss of economic activities, starvation or malnutrition, biodiversity, the spread of diseases, and so on. Drought is not aridity or desertification. Aridity is a dominant feature of dry regions, which refers to permanent conditions of low average precipitation. Water destruction and degradation of land resources may lead to desertification of an area, which originally was not arid region [9].

### 3.4 Climate Change and Drought Impacts on Nature

Climate change impact is now a globally important issue in society from different socio-political considerations. Drought may lead to desertification or aridity if it prevails for a prolonged period accompanied with destructive land use practices [57]. Based on Warren [85], drought occurs when the moisture supply is abnormally below average for a period of up to 2 years. The types of drought need to be distinguished in order to understand the causes and effects. The types of drought to be considered are meteorological, agricultural, seasonal, hydrological, socioeconomic, land use, and cultural issues. The natural resources that are linked within these potential factors are those affected due to drought and water scarcity. The major division of natural resources is water, soil, forest, mining, and air resources. All these factors are the elements of weather and ecosystems. These are now being affected by drought extension in different parts of the world as well as in Bangladesh [81,82].

#### 3.4.1 Impacts on Natural Resources

Species extinction appeared to be occurring at an unrivalled rate during the early 1990s. The International Union of Nature Conservation (IUCN) reports suggest that 25% of mammalian species are threatened with extinction. Out of a total 4327 mammal species, 1096 are regarded as at risk, while 169 are classified as critically endangered [65]. The loss of species diversity has become a global problem and unintentional and intentional human modification of habitats is the main threat to species [16,65]. Phillips and Mighall (2000) explained and stated that if the trends are not reversed, up to 50% of the world’s species will become extinct over the next 50 years, with the annual estimated rate of extinction between 10,000 and 20,000 species [65]. Abramovitz [7] argues that human activities are creating a biodiversity deficit—by destroying species and habitats faster than they are being replaced with new ones—of 100–1000 times. All areas of human activity appear to be threatening biodiversity; commercial exploitation, illegal hunting and poaching, land use changes, and pollution all have direct or indirect effects [31,50,69]. Abramovitz also suggested that whole ecosystems are under threat, and reducing their size and integrity inhibits nature’s capacity to evolve and create new life. The tropical reef ecosystems are diminishing as a result of habitat-destructive fishing techniques and mining that adversely affect all trophic levels. Furthermore, wetlands and mangrove cover are dwindling as they are reclaimed for agricultural and residential use, are submerged by dam/barrage schemes, or are used as rubbish dumps or for aquaculture [2,65]. In such conditions, the 1973 Endangered Species Act works on the very eccentric principle that all life-forms may prove to be valuable sometime in the future and therefore each is entitled to exist for its own sake. Thus, the act contains power to protect any species that is considered, based on the results of scientific research, to be close to extinction, and 109 species were deemed to be either endangered or threatened in 1973; the number has since risen to over 900, with a further 3700 officially recognized candidates [51].

#### 3.4.2 Impacts on Soil and Water Resources

Due to upstream fresh water extraction from river basins and sea level rise, temperature increase is also producing harmful soil and a degraded water environment in different parts of the coastal regions [39]. Drought is pushing endangered salmon in California to the brink. They were already endangered in the
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Sacramento River, but the record drought parching of the western United States has brought the iconic fish even closer to extinction, as the king salmon needs very cold water for its eggs to develop. The present water salinity value in Bangladesh ranges from 54,025 to 69,152 dS/m and relates to an area that has been extended from south to north and east to west and which is extremely high, threatening the mangrove ecosystem services in the Sundarbans regions as well as in the whole Gorai catchment area \[32,35,37\]. Dry season salinity along the Nabaganga–Rupsha–Passur river system has largely been influenced by the dry season flow of the Gorai River. The trend of water salinity in the region is at an extremely high rate for agricultural crop cultivation and is even harmful for animals, fisheries, livestock, and agrobiodiversity \[39\]. As per an earlier soil investigation conducted by Soil Resource Development Institute (SRDI) in 1970, the soil salinity was mainly found in the Ganges tidal floodplain of the study area. The floodplain and the peat basins in the area were classified as a nonsaline zone where the soil salinity range was between 6001 dS/m to 8644 dS/m during the dry season (November–May) \[32,39\].

Since the withdrawal of water from the Ganges River there has also been extensive withdrawal of groundwater due to drought and agricultural irrigation; subsequently, saline groundwater and seawater from the south are intruding into the fresh water aquifers in the north. This salinization process is steadily overwhelming the local agro-ecological systems \[39\]. Therefore, the reduction of ecosystem services could be mainly attributed to the action of humans in the environment. A UN report stated that almost 50% of land had been highly degraded by anthropogenic influences \[80,83\]. The coastal land and wetlands are under pressure because the Asian coastal region contains more than 52% of the world’s population \[70\]. By 2050, the number of countries facing water stress will rise to 18, affecting 600 million people. This future water stress and scarcity will have serious impacts on the socioeconomic improvement of the countries and will probably adversely affect their food production levels. It is likely that global warming and drought impact will affect the production of certain crops, such as rice, wheat, corn, beans, and potatoes, which are major food crops for many countries in Africa, Latin America, and the Asian continent \[33\]. The increase in temperature would be one of the root causes of a reduction of agricultural crop production. A case has been shown in Zimbabwe where the temperature has increased from 2°C to 4°C, which is changing the farming system and reducing the maize production rate; farmers need extra irrigation costs for agricultural production as soil fertility and water availability are becoming reduced \[33\].

3.4.3 Impacts on Mining and Mineral Resources

Global climate change is due to human-induced emissions of greenhouse gases, but local climate change is due to urbanization and land use change \[43\], which affects people’s well-being through damages to their health \[42\]. Land use change affects the local climate by affecting the provision of ecosystem services (ES) \[68\]. The ecological, social, and economic impacts of climate are geographically unevenly distributed \[53\]. Mineral extraction and loss of traditional livelihoods are creating huge social problems and community migration, land use change, and occupational changes in different parts of the world. The more socio cultural occurrences are like displacement of people and settlement from mineral and mining regions, decline in access to natural resources, increase competition among local for resource uses and collection, and conflicts among farmers, stakeholders, and researchers. The Indian state of Orissa has achieved phenomenal economic growth largely from the mining and infrastructure sectors. The livelihoods of the large tribal population depends on natural resources, and due to stakeholders’ pressure, drought impacts, and extreme weather events in the last decade, the traditional livelihood of people in Orissa has changed. The state is rich in mining and mineral resources, which are 24% coal, 17% iron ore, 98% chromates, 51% bauxite, and 35% manganese. There are 596 mining sites were leased with an area of 9,662.5 km², which contributes 7% to the state.

3.4.4 Landscapes and Land Use Changes

In this millennium, global drylands face a myriad of problems that present tough research, management, and policy challenges. The recent advances concerning sustainability, together with the integrative...
approaches of global change and sustainability science, suggest that concerns about land degradation, poverty, safeguarding biodiversity, and protecting the culture of 2.5 billion people can be confronted with renewed option. In many regions of the world, landscapes and land use are changing due to drought impacts and climatic harshness. The Sahel region is in sub-Saharan Africa, a transition zone between the tropical south and south central Africa and the Sahara desert, which are continuously changing their land use patterns [63,64]. The hyper-arid type of climatic condition is continuously moving southward due to climate change impacts such as drought. The Saharan region and other sub-Saharan countries share similar economic activities, namely, agriculture, forestry, livestock, and small agro-based industries [24,25]. Approximately 70% of the population of the sub-Saharan region depends on agriculture or related agricultural activities for their livelihoods. Today in the Sahel region, land use is changing to agricultural, with arable and pastoral farming providing an agro-ecosystem [44].

The region is experiencing a strong variation of climatic conditions with years of extreme dynamics (rainfall variations from 200 to 600 mm) and a reduction of rainfall leading to extreme droughts [9,13]. As landscapes and land use are continuously changing to agricultural farming only a few trees now exist on the Sahelian horizon, impacting both climate and anthropogenic disturbances. Figure 3.1 shows the consequences of land use changes that lead to degradation, dryness, and desertification in different geographical regions of the world. Natural land use changes very frequently in the Sahel region.

In Colombia, drought threatens one of the world’s top coffee producers, the farmers of coffee beans located at 5900 ft on the slopes of the Galeras volcano. Nariño, in south-western Colombia, is certified as a top coffee producing region for its mellow-tasting, fine-smelling produce. More hours of sunlight means a higher concentration of sugar in the grain, but extreme weather is making it an ever greater challenge to keep producing the cherished beans for the world’s cafes. But the recent water shortage is stressing farmers’ coffee plants. Stalks have flowered and could yield a record crop, but they need more rain to do so. Reduced rain in South America in 2015 has caused a severe drought in Colombia. This type of drought could change the agro-landscape in Colombia as well as the microscale scenarios, as has been seen in other parts such as the Middle East and Asian countries. The north and north-west regions in Bangladesh are facing a serious scarcity of water and droughts which are appearing these days. The following model of land use change patterns is seen in the case areas in Bangladesh. In model (Figure 3.1) shows the land use changes due to extensive use of agricultural land, settlement development urbanization process in the rural Bangladesh as well as other parts of the world.

All these activities and climatic conditions have accelerated the totality of soil that is bare and open to wind erosion during the dry seasons [62,84]. The continuous reduction of topsoil through erosion due to poor conservation practices provides grounds for the reduction of vegetation cover and, when the soil

![FIGURE 3.1](https://example.com/figure3_1.png)

**FIGURE 3.1** Consequences of land use change and degradation in the Sahel region of the African continent and other drought-prone and dry areas.
below the topsoil is compact, most of the rainfall water runs off into waterways [19,24]. The impacts of dryness and drought reduce vegetation cover that still go along with reduction of water recycling and monsoon circulation, thus a continuous decline in preparation of land use change and damage of agricultural crops production in the African Sahel and sub-Saharan regions.

### 3.4.5 World Forest and Vegetation Cover Changes

Forest is the most important and potential natural resource for world food security and economic and industrial development. Forest resources provide food and industrial raw materials as well as economic effects in the global market. Forest covers 4.03 billion ha globally, approximately 30% of the earth’s total land area [23]. It accounts for 75% of terrestrial gross primary production and 80% of the earth’s total plant biomass and contains more carbon in biomass and soils than is stored in the atmosphere. Almost 31% of the earth's total forest area is found in Asia (including Asian Russia), followed by 21% in South America, 17% in Africa, 17% in North and Central America, 9% in Europe, and 5% in Oceania [23].

Globally, 5% of forests are plantations, generally used for commercial purposes. Some 46% of the tropics (1.9 billion ha) is covered by forest and half of this can be reasonably termed rainforest (Table 3.1). This forest type—at its most dramatic it is a multilayered, dense, evergreen forest, 45 m or more tall, with a forest micro-climate quite distinct from that of non-forest areas—is characteristic of the equatorial regions of all the major continental areas and which, where climatic and edaphic conditions allow, extends to the boundaries with the temperate zones [86]. The consequences of tropical deforestation operate at global, regional, and local scales and include the following:

- Losses of plant and animal biodiversity as a result of habitat destruction and modification
- Changes in global carbon mobilization from soils and vegetation consequent on land use change and global climate change
- Soil erosion, disruption of nutrient cycles, and soil fertility
- Alterations to hydrological regimes and water quality and downstream sites [77]

Table 3.1 shows the tropical and subtropical rainforest scenarios of the world; four geographical regions are categorized [77]. Forests around the world are now subject to the risk of high rates of tree growth decline and increased mortality due to a combination of climatic warming and drought, notably in semiarid settings. Forest growth has declined since 1994 and in inner Asia has been confirmed to semiarid forests. Fire occurrence and insect/pathogen attacks have increased in tandem with the most recent (2007–2009) documented episode of tree mortality. If warming in inner Asian countries further increases then forest stress and trees mortality might drive the eventual regional loss of current semiarid forests. Climate warming and drought have affected tree growth in one of the world’s most extensive zones of semiarid forests in inner Asia, a region where a lack of data limits our understanding of how climate change may impact forest resources in Asian, African, and Latin American countries. It is also important issue for consideration that how climate change affecting on the coastal

### Table 3.1 Major Areas of Tropical Rainforest

<table>
<thead>
<tr>
<th>Geographical Regions</th>
<th>Area (x 10^4 km^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Americas (Amazon–Orinoco; Pacific South, America–Central America; Atlantic Brazil)</td>
<td>4.0</td>
</tr>
<tr>
<td>Malaysia and extensions (Burma–Thailand–Indo-China)</td>
<td>2.5</td>
</tr>
<tr>
<td>Papua New Guinea, North Australia, Sri Lanka</td>
<td>1.8</td>
</tr>
<tr>
<td>Africa (Central–West Africa; Madagascar)</td>
<td>8.3</td>
</tr>
</tbody>
</table>

mangrove forest resources, since mangrove forest is very important for livelihoods in many Asian, African, and Latin American coastal communities [40].

The world’s tropical and subtropical mangrove forest wetlands are found along tropical and subtropical coastlines, usually between 25°N and 25°S [72]. The world’s mangroves predominate in Indonesia 24%, Brazil 7%, Australia 6%, Nigeria 6%, Cuba 4%, India 4%, Malaysia 4%, Bangladesh 4%, Papua New Guinea 3%, and Mexico 3%, with the rest of the world at 35% (Figure 3.2) [36, 54]. Recent climatic impacts like high temperature and drought and dryness have manifested as large fires, such as the Rattlesnake Fire in the Coronado national forest (Arizona in United States) which is about 28,000 acres and the Coffee Pot Fire in Sandia national forest (New Mexico, United States) which is about 22,000 acres. These fires have drawn attention to the vulnerability of large numbers of communities. Similar forest fires frequently occurred in 2003 in Australia, Brazil, Russia, and Greece and in other parts of Europe, Latin America, and Caribbean countries.

3.4.6 Impacts on Global Wetland Resources

The world’s wetlands play a potential role from an economic and ecological point of view. Particular interest has been shown to a number of wetlands around the world with regard to their extent, uniqueness, and attributes. This includes coastal and inland deltas, riverine wetlands, salt marshes and mangroves, freshwater marshes, and peat lands. They are found on every continent except Antarctica and in very rough climates from the tropics to the tundra. A total of 750,000 km² of wetlands were registered with the Convention on Wetlands of International Importance as of 2000 (Figure 3.2) [54]. According to the RAMSAR 1971 (The Convention on Wetlands of International Importance especially as Waterfowl Habitat) Convention, article 1.1, the term “wetland” links together a wide range of inland, coastal, and marine habitats, which share a number of common features [52, 67]. Usually, wetlands occupy transitional zones between permanently wet and generally dry environments [20]. In Bangladesh, there are permanent wetlands and seasonal freshwater lakes and marshes of floodplains, which are known by different names: (1) haor (a bowl-shaped depression between the natural levees of a river mostly found in the eastern region of greater Mymensigh and Sylhet districts); (2) baor (an oxbow lake, being the
dead arm of a river situated in the moribund delta of the Ganges); and (3) beel (the lowest part of the floodplain landscape, usually a saucer shaped wetland) [5,41,66].

Wetlands in different parts of the world have great significance for a country’s economic, industrial, ecological, socioeconomic, and cultural context [35]. They contain very rich components of the biodiversity of a valuable ecosystem [48], which serves as a habitat for a variety of resident and migratory waterfowl and endangered and commercially important species of national and international interest [38,60]. Moreover, it supports a rich biodiversity of flora and fauna, which substantially contributes to socioeconomic improvement for millions of people living especially in rural areas. This livelihood sustainability provides opportunities for employment, food and nutrition, fuel, fodder, transportation, and irrigation [60]. The wetlands of developing countries such as in Asia, Latin America, and Africa have suffered drastically from the impacts of a burgeoning human population and anthropogenic activities on the wetlands. Yet, wetlands are recognized as a driving force for biodiversity conservation and rural socioeconomic improvement [4,60,61]. The smart use of wetlands can solve the ecosystem problems in floodplain areas.

In the south Asian Ganges–Brahmaputra–Meghna floodplains alone, approximately 2.1 million ha of wetlands have water resources that are essential to human development processes and to achieving the millennium development goals, which seek to alleviate extreme poverty and hunger and to ensure environmental sustainability. The regional hydrology and wetlands are affected by natural calamities, anthropogenic influences, and climate change impacts. Most parts of the tropical and subtropical regions face hydrologic and water scarcity problems. Recurring water-related natural hazards, such as floods, cyclones, droughts, and a decline in water availability, combined with deteriorating quality, have undermined the local health and livelihoods of millions worldwide especially in the developing countries. Therefore, wetlands also suffer from different types of disturbances and are gradually sinking due to agricultural farming, settlement extension, and urbanization activities in Asia, Africa, Latin America, and even in Europe (Figure 3.3) [4,59,72].

FIGURE 3.3 Distribution of global wetlands resources (including mangrove wetlands). (From U.S. Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS)-Global Distribution of Wetlands Map, USDA-NRCS, Soil Science Division, World Soil Resources, Washington, DC, 2003.)
There are thousands of wetlands distributed in different parts of the world, with the 10 greatest distributed across the different continents and across different climatic conditions:

1. Pantanal (Brazil) is the world’s largest wetland, lying mostly in western Brazil but extending into Bolivia and Paraguay as well. It covers a region of 140,000 km².
2. The Sundarbans (Bangladesh and India) is the largest littoral mangrove wetland and covers an area of 10,000 km².
3. The Okavango Delta wetland (Botswana) is formed where the Okavango River empties into a basin in the Kalahari Desert and is 15,000 km².
4. The Everglades (Florida) covers an area of 512.4 km².
5. The Kerala Backwaters (India) extend for 590 km along the coast with the largest lake covering an area of 200 km².
6. The Kakadu wetlands (Australia) cover an area of 19,804 km².
7. The Mekong Delta wetlands (Vietnam) cover an area of 40,000 km².
8. The iSimangaliso Wetland Park (South Africa) covers an area of 3280 km².
9. The Wasur National Park (Indonesia) covers an area of 4138 km².
10. The Camargue wetlands encompass the Rhone River Delta in the south-east of France and cover an area of 1503 km² (Figure 3.3) [40].

In Bangladesh, the wetlands have suffered from an increase in the human population, and approximately 2.1 million ha have been lost to flood control, drainage, irrigation development, and other human developmental activities [60,61]. There are only 43 designated wetlands, and most of them are under threat from indiscriminate utilization, encroachment and reclamation, urbanization, agricultural development, and flood control. Almost 50% of the country’s people are directly dependent on wetland resources [73]. The vast majority of poor people in wetland areas are dependent on their resources for their nourishment [38,40]. Therefore, a balance between the hydrologic water cycle and natural resource management plans and policies are needed to conserve these invaluable unique wetland sites [40].

Approximately 14 million ha of mangrove wetland areas are generally dominated by the red mangrove species (Rhizophora) and the black species (Avicennia) [54]. The present world mangrove vegetation cover has been estimated at an average of 17 million ha, of which half is in the Asia–Pacific region. The remaining 50% is equally distributed in Africa and America [33,40,49]. The modern approach to wetland construction is to include a potential role for socioeconomic improvement. In general, millions of industrially constructed wetlands have been used to treat wastewater or conventional water with different characteristics throughout the world every year, including domestic wastewater, various types of industrial wastewater, agricultural wastewater, and storm water.

### 3.4.7 Drought Impacts and Risk Analysis

The present trend of natural calamities and hazards, such as floods, droughts, rainfall, cyclones, earthquakes, and anthropogenic disturbances, are gradually increasing the vulnerabilities in different climatic regions of the world. Water scarcity and drought are the greatest challenges to maintaining food security and nutrition balance in communities. Some African countries are facing extremes of drought and dryness, which accelerate the negative slow speed of agricultural crop production and maintain the balance of ecosystem services and water supply for drinking and agricultural irrigation. The countries facing extreme drought problems include Somalia, the Democratic Republic of Congo, Haiti, Burundi, Chad, Ethiopia, Eritrea, Afghanistan, South Sudan, and Comoros. These countries are under extreme risk of a food and nutrition crisis. The following countries suffer from high drought, food security, and nutrition risk: Cambodia, Laos, Yemen, Iraq, Iran, India, Pakistan, Myanmar, Bangladesh, Libya, Sudan, Nigeria, and some other African countries. The following countries fall under a middle drought risk: Mexico, Brazil, Russia, China, and all countries of South America. The only few countries where
there is no environmental or drought problem and which have food security include European Union members, the United States, Australia, New Zealand, Japan, and Chile.

The desertification vulnerability map (Figure 3.4) is based on a reclassification of the global soil climate map and global soil map.

### 3.4.8 Air Quality and Temperature Changes

Temperature change, air quality, and drought impacts are interlinked and in general are damaging the quality and quantity of natural resources. Particularly in the tropical and subtropical areas, agriculture is frequently seen as the antithesis of the natural world, where the problem is framed as one of minimizing land devoted to agriculture so as to devote more conservation of biodiversity and other ecosystem services. Surface agro-ecological practices have endured from time immemorial on a traditional basis. Temperature change, industrial gases, and climate change all impact agricultural lands and forest landscapes in different surface and coastal marine regions of the world.

The Intergovernmental Panel on Climate Change (IPCC) [33] has already estimated the scale of temperature change from 1901 through 2015, temperature rose at an average rate of 0.13°F per decade and the scale of the global sea-level rise has been assessed at 4 mm/year [33]. This temperature and sea-level rise is a new threat to natural resources, agricultural productivity, coastal urban life, and low-income community livelihoods and their health and life security. Traditional agro-ecological practices are so far poorly integrated in the actual agriculture systems of the world as there are so many climatic, anthropogenic, and industrial changes in play. The quality of the air, water, soil, temperature, and coastal marine ecosystem should be considered in relation to sustainable agriculture and industrial production–based planning. These agro-ecological practices have only a moderate potential to be broadly implemented in the next decade. By contrast, the following proposed future practices should be integrated: organic fertilization in agricultural production, biological pest control, afforestation programs to control the high temperature increase, and a sustainable manner of industrial development and urbanization planning.
3.4.9 Impacts on Fisheries and Livestock

Water resources in rivers all over the world supply fresh water for irrigation, fishing, and livestock development. In Bangladesh, major rivers are the main sources of fish. Fishing is important in Bangladesh but is not the main source of food or occupation, which is why this sector is not economically dominant. In Bangladesh, it has been estimated that 10,000 tons of fish were caught in the 12 months of 1993–1994, as a whole in that year of 1.09 million tons and government declared this figure of which 13% came from rivers and estuaries [17]. The river area in Bangladesh has been estimated at about 8400 km$^2$ for the total area of main river char lands, and at 2200 km$^2$ for the midland char lands, for 1980; the total area of fishing water is 67,000 km$^2$ [17]. The socioeconomic implications of fish culture as a livelihood source for communities living in char areas were also considered regarding their future development. The present status of Bangladesh as well as in other parts of the world is one facing a serious water scarcity problem to protect and conserve the water shade and water bodies for fish cultivation due to anthropogenic impacts to huge uses of natural resources and climate change impacts are most serious climatic barriers. The previous study findings on global scale has estimated that the economic value of ecosystem services lost through deforestation could be as high as USD2–4 trillion each year [26]. Many parts of the large river catchment areas are declining due to river erosion and natural calamities, especially in the coastal regions. Many of these types of extensive threats on grasslands which are used for cattle reared by local communities which products were met up the demand of the local and national demands for food security and nutritional demand fulfilling in tropical and subtropical regions as well as in South Asia and in Bangladesh.

3.4.10 Drought Impacts on Biodiversity and Ecosystem Services

Managing biodiversity in the face of natural calamities and anthropogenic disturbances is the most serious issue today. It is usual to think of biological diversity as more about plants, animals, and microorganisms and their ecosystems than about people and our need for food security, medicines, fresh air and water, shelter, and a clean and healthy environment in which to live. Maintaining the earth’s biodiversity is essential for the natural environment to deliver the goods and services on which humanity thrives. It is furthermore a key dimension of poverty alleviation. Natural calamities, anthropogenic influences, and climate change impacts are now the major threats to biodiversity protection and keeping ecosystems friendly. The United Nations, the European Union, Asian nations, and the African community are now actively concerned with biodiversity conservation and the protection of ecosystem services. The European Union (EU) estimated that by 2020 the global comments made in Nagoya in Japan in October 2010 in the context of the Convention on Biological Diversity (CBD) its set of 20 global targets. Some regional political associations and environmental research institutions have already started to orient plans for the implementation of CBD target strategies. The EU has outlined six most important strategies which are targeted by 2020 actions and these are formulated for actions and among them two are very potential strategic actions are the maintenance and protection of agricultural and forestry ecosystems. Other important actions are to maintain and restore ecosystems and their services and to increase the contribution of agriculture and forestry to maintaining ecosystems and biodiversity [22].

Climate change impacts, such as floods, cyclones, tornadoes, salinity intrusion, dryness extension, water scarcity, and drought, are threatening biodiversity and ecosystem services. Most parts of the earth’s surface are facing severe climatic and anthropogenic impacts. Habitat conservation and biodiversity loss, water scarcity and pollution, greenhouse gases, soil erosion and degradation are all relevant to agricultural crop production and community livelihoods in cold, tropical, and subtropical climatic regions [22].

3.5 Drought Impacts on Natural Resources: The Bangladesh Case

Drought is one of the most severe natural disasters in northern Bangladesh and causes immense suffering to people in various ways and threatens natural resource management [56]. In 1975, Bangladesh experienced a severe drought; 47% of the area and 53% of the population were affected. Monsoon rainfall, although very
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heavy compared to surrounding areas, suffers from extreme variability, often exceeding 60%. The lower the amount of rainfall, the higher the variability holds good in the north-western and south-western parts of the country [34]. Drought affects agricultural food production and human life in general in the north, but is gradually extending in a southerly direction [1,11,18,56]. The constructed wetland resources in Bangladesh can be seen on a very small scale [40]. Their management and regional hydrology is not in good shape worldwide, nor is it in Bangladesh [40]. A vast area of wetlands is lost due to flood control, drainage, and irrigation development—in Bangladesh as well as in other countries [46], hence forest and wetlands are facing serious challenges from environmental changes and anthropogenic impacts (Figure 3.5) [59,72].

![Forest and wetland distribution in Bangladesh.](image-url)
There are five types of wetland resource in Bangladesh: saltwater, freshwater, palustrine, lacustrine, and man-made. The important wetlands, forest patches, and river network patterns are shown in Figure 3.4. Presently, most of the wetlands in the country are under threat due to unsystematic utilization, encroachment and reclamation, urbanization, agricultural development, and flood control actions [27,46,60]. The protection and management status of wetlands in developing countries is more or less complex and severe due to financial, technical, social, and political decisions, as well as a lack of integration of those sectors [28,36,79]. The degradation of natural resources, especially land and forest, has become a subject of serious concern because the vast populations of these countries have to rely on these resources for their livelihoods [21]. Agroforestry, a land use system of growing different species of woody perennials in association with field crops, is a suitable system specifically for degraded areas. It helps to control soil erosion, hold back environmental degradation through the biological interactions of trees and crops, and increase income from farmland [29,47,71].

The land use system within agroforestry has been considered to be an effective and low-cost method as it does help to minimize the process of degradation associated with land cultivation and also for its retention of the ecosystem [8]. This method is widely used as a scientific instrument assuring food security, alleviating poverty, and enhancing ecosystem resilience with smallholders in the tropical and subtropical regions [47,76]. In Bangladesh, the total agricultural land use was about 1,000,370 km$^2$ (71.1%) in 1990 and was 940,000 km$^2$ (72.2%) in 2000. In general, the forest area was about 8,820 km$^2$ (6.8%) in 1990, 14,680 km$^2$ (11.3%) in 2000, and 1,440 km$^2$ (11.1%) in 2010. On the other hand, Bangladesh contains 1245 km$^2$ of inland moist deciduous Sal (Shorea robusta) forest, which is widely known as Vhawal—Madhupur Terrace and Sal Forest and extensively distributed in the districts of Dhaka, Gazipur, Tangail, and Mymensingh, other patches of Sal forest are distributed in Comilla, Dinajpur, and Rangpur districts (Figure 3.4) [6]. In recent years, most of the Sal forests have been severely damaged by anthropogenic activities like illegitimate felling and infringement by the local people and the Garo tribe in the Madhupur area of Tangail district [6,47]. Through the community activities the agroforestry system has developed over there which is the new threat for the Sal forest conservation. The Sundarbans mangrove forest is located in the southern coastal area and covers 6000 km$^2$, but the recent sea-level rise and salinization process has affected the forest (Figure 3.4). Consequently, the entire coastal region of 47,000 km$^2$ has gradually been affected by a different degree of saline water, which is a threat to agricultural crop production as well as fishing and livestock rearing in the region. This is harmful to nutritional values, food security, and community livelihoods in coastal Bangladesh [6,40]. A comprehensive analysis of various issues leading to forest, soil, and water resource and wetland degradation in the Bangladesh case area has been analyzed (Figure 3.4). This comparative analysis of the different cases in different climatic regions has been carried out on Bangladesh as a model case through applied research findings on natural resources uses, management, and sustainability efforts [78].

### 3.6 Approach of Capacity Building and Drought Management Plans for Sustainable Usage of Resources

In global scale the natural resources are using abstractly according to the demand of the regional and national population. The present global population figure is over 7 billion in 2007 and is expected to increase to more than 9.1 billion in 2050. That means by 2050, 35% more food will be needed for the global population. Therefore, natural resources could be used more often without a sustainable plan. The amount of natural resources reduces due to large-scale use; and climatic impacts can be considered as a new threat to the conservation and management of natural resources. The triangle approach of utility and planning is illustrated in the model (Figure 3.5), which shows the uses of planning and future sustainability for natural resources.

Figure 3.5 shows the model where three triangle approaches are combined within the set of this following model. The triangle diagram model represents three potential subjects, such as ecology...
and ecosystem approach, socioeconomic and cultural aspects and productive usable aspects are three core issues which cover the environmental, economic, and productive issues. Based on these three topics, the natural resources could be used in a sustainable manner and wisely within the circular areas displayed in the inner site of the triangle approach of resource management. Through using this approach the future natural resource use could be possible within a development planning framework in all three climatic regions, such as the cold, tropical, and subtropical climatic regions in the world.

The concept and the findings of this study are illustrated that some recent initiatives have been undertaken by the Ministry of Environment and Forest, the Ministry of Land, and the Ministry of Water Resources of the Bangladesh Government. Most of the developing countries’ natural resources are not strictly controlled for conservation and management, as there are not enough laws or state legislation established. In general, natural resources such as soil, mining, forest, and fresh water are controlled by local elite groups and multinational companies. In such a process, international politics play a leading counterpart role in maintaining and controlling natural resources. Actions that are aimed at retaining natural resources have been undertaken to a lesser extent [40].

Climate change impacts such as drought, water scarcity, and salinization are more common features seen in the tropical and subtropical regions of the world. At the microscale, drought and water scarcity and salinization problems are recurrently affecting natural resources in Bangladesh which severely threatens environmental protection, health, and food security in the country. The rising groundwater level in wetland areas may increase evapotranspiration, and as a result there may be reduced runoff in the summer period. The freshwater wetland sites in the country are losing their hydrological cycle and scarcity of freshwater is creating ecological damage in different wetland sites all over the world as well as in Bangladesh. On the other hand, the mangrove wetland sites of the southern coastal region of Bangladesh are affected by saline water intrusion and degradation of water quality. The study result also reveals that the authorities do not follow any policy guideline or appropriate management approaches for natural resources conservation, either in Bangladesh or in most of the developing countries in Asia, Africa, and Latin America [39,58]. Figure 3.6 illustrates the model of natural resource use sustainability,

FIGURE 3.6 Natural resource utility, future development planning, and sustainability.
which could be extended with the conceptual model of Figure 3.7 and which could jointly ensure the use, conservation, and management sustainability of natural resources.

Considering the present management and conservation scenarios of natural resources due to climate change and environmental calamities and the study findings, the following natural resource management model (Figure 3.7) has been developed for proper implementation in the cold, subtropical, and tropical climatic regions where natural resources are strongly affected by drought and anthropogenic disturbances; however, the quality of human capacities is not developed based on climate impact issues [75].

In the model of natural resource management and use sustainability, the fundamental environmental factors and elements are closely interconnected and balance ecological and ecosystem functions (Figure 3.7), which are dependent and linked with other elements and factors and institutions.
such as governance, population growth, the industrial estate, and urbanization process within the particular climatic region. The other potential factors include wetlands, water availability, soil quality, temperature, drought, forest patches, landscapes and land use, agricultural practices, biodiversity, ecosystem, and food security. All these elements, factors, and social, political, and economic aspects are interlinked for the protection and management and future sustainable use of natural resources (Figure 3.8).

Considering the climate change impacts and hostile environmental phenomena such as drought, floods, salinization, and natural calamities the fundamental elements of natural resource management and sustainability are adapted and illustrated in the conceptual model (Figure 3.8). The policy framework includes the following elements: (1) institutional support, (2) planning and policy support, (3) landscape, land use, and biodiversity support, (4) livelihood support, (5) organizational support, and (6) indigenous support [40].

The natural resource management situation and its ecological, socioeconomic, cultural, and environmental impacts are tragic in all climatic and geographical regions as well as in Bangladesh [35,41]. Natural resources have been used from time immemorial, but there have not been sufficient rules and regulations either in developed or developing countries. Some important national and regional laws and legislation were established in different countries in the twentieth century. The most well known are those in the United States, like the River and Harbors Act 1899, the Geothermal Stream Act 1970, the Clean Water Act 1972, the Geothermal Energy Research, Development and Demonstration Act 1974, the Safe Drinking...

In Bangladesh after the UN Stockholm conference in 1972, the government initiated environmental programs for the first time with the creation of the Department of Pollution Control in 1974 and the enactment of the Pollution Control Ordinance in 1977. In 1989, the Ministry of Environment and Forestry was set up with the Department of Forests and a newly created Department of Environment under it. On April 13, 1992, the Draft Environmental Policy 1990 was approved by the Cabinet [34]. The National Water Policy was developed in 1999. The environmental policy statement describes six main objectives: (1) to help conserve and develop the ecological balance, (2) to save the country from natural catastrophes, (3) to identify the nature of all sorts of pollution and control, (4) to ensure durable development in a sphere suiting the demand of the environment, (5) to ensure judicious and long-term use of all national resources, and (6) to keep the nation alive to all international steps in connection with the environment as far as possible [34]. The National Wetland Policy also drafted in Bangladesh includes the following issues: maintenance of biodiversity and landscape protection, maintenance of ecosystem functions and ensuring socioeconomic benefits, and promotion of economic development and the establishment of principles for the utilization of sustainable resources [40].

For better planning and sustainable management of natural resources, the fundamental model, structure, and policy framework, and its prime factors and subfactors, should follow properly. The conceptual model (Figures 3.6 through 3.8) should be implemented in different climatic environmental locations as well as in Bangladesh and could achieve a good result for better management that could ensure livelihood sustainability for the communities and stakeholders who believe and would like to protect natural resources for future generations [14,15]. The findings of this chapter could become an important framework for planning and the sustainable management of natural resources and the conservation of ecologically sensitive sites in Bangladesh as well as in other parts of the world.

3.7 Summary and Conclusions

Natural resources are the most important driving force for socioeconomic and industrial development. They are the only source of food security and economic activity all over the world. Human resources and habitat and microorganisms are directly dependent on natural resources. The present rapid population growth and unplanned extraction of natural resources could be the future severe in-scarcity of natural resources that could be beyond of under control. Climate change impacts as well as drought are new threats to the control, management, and conservation of natural resources in cold, tropical, and subtropical climatic regions in the world. They have the ability to focus tremendous energy and to generate significant creative and economic betterment. In general, a country’s wetland natural resources as well as its ecosystems become degraded due to anthropogenic influences and natural calamities.

Water scarcity and drought are creating imbalance of the hydrological cycle of wetlands, and forest regions are losing their balance to protect ecosystems in the particular case regions in Bangladesh and other similar regions of the world within the three different climatic conditions. Therefore, all these countries need adequate interdisciplinary policy, framework strategies and the political will to implement it for the sustainable management and protection of natural resources especially in the sensitive ecosystems regions like Bangladesh and other developing countries. The methods for the generation of transformative knowledge to achieve and maintain natural resources, agro-farming system development, fishing development, and in general the wise use of natural resources that could protect ecosystems, biodiversity in the cold, subtropical, and tropical climatic areas.

For any kind of research project, implementation that is harmful to the sensitive ecology in different climatic zones and political territories as well as in Bangladesh should follow the integrated strategies for sustainable natural resource protection.
The following issues are strongly recommended for the implementation on a global as well as a regional and national basis for the better management of natural resources:

- Increase public awareness concerning environmental monitoring, training, and education, particularly where related to the importance of the sustainable use of global natural resources for better achievement from ecosystem services.
- To provide information to the global, rural, and urban communities concerning potable drinking water and natural resources collection, properly uses for making balance of ecosystem services for long-term protection measures.
- Ensure community involvement in maintaining and protecting the quality, development, and management measures of global natural resources.
- Transfer technology and awareness knowledge to global, urban, and rural communities for the sustainable use of urban ecosystem goods and services in remote areas for socioeconomic and livelihood improvement and to ensure environmental sustainability.
- Continue environmental discourse and dialogue for understanding the importance and inevitability of capacity building skills to protect landscapes, land use, water, soil and forest resources, and their appropriate use within drought hazard conditions in different climatic regions.
- Develop and train up the capacity building of global communities, local governance, stakeholders, NGOs, national policy makers, and planners who are directly or indirectly involved in biodiversity conservation and natural resource management planning activities.
- Encourage technologies and special skills that restore ecosystems through entrepreneurs’ investment in environmentally sound technology. Also improve the use of relevant information that can enhance and sustain the capacity to assess the consequences of ecosystem changes through productive data and information-based actions.
- Good governance should be the basic concern of capacity building and skills development, which could be used for natural resource allocation, protection, and management. The changes in institutional and environmental governance frameworks to enable effective management of ecosystems as such will ensure the sustainability of natural resource and protective management.
- Policy, principles, plans, a program for sustainable natural resource management, and specific guidelines should be more precise and concrete. The national natural resources management and use policies should be implemented properly; in addition a policy guideline of management issues should be incorporated in national resource policy in Bangladesh where it is necessary for the better management of ecosystems services and the improvement of the urban and rural socioeconomy. Therefore, an integrated global drought mitigation and adaptation policies and guideline framework should be prepared based on this study’s findings and drought smart environmental planning is urgently needed for a sustainable natural resource development and protection of ecosystem services in Bangladesh and other climatic regions.

Authors

Shafi Noor Islam is an assistant professor in the Department of Geography and Development and Environmental Studies at the University of Brunei Darussalam, Gadong, Brunei Darussalam. Previously, he was a lecturer in euro hydro-informatics and water management at the Brandenburg University of Technology Cottbus-Senftenberg, Cottbus, Germany. He holds a PhD in environmental and resource management and has worked as a lecturer on the master’s program in urban management studies at the Technical University of Berlin, Germany. He has also worked as a visiting lecturer on the master’s program on environmental and applied science at Halmstad University, Sweden. He has postdoctoral research experience in food security and is presently a habilitation candidate at the Brandenburg University of Technology Cottbus-Senftenberg, Germany. His main activities are in interdisciplinary water resource research on water salinity and mangrove ecosystems analysis. He has published 50 articles in international
journals and books. He has research experience in China, Malaysia, Indonesia, Germany, Poland, Denmark, Italy, Spain, France, the Netherlands, Sweden, and Mexico.

**Sandra Reinstädter** (Dip Eng) is a doctoral research associate in the Department of Environmental Planning at the Brandenburg University of Technology Cottbus-Senftenberg, Cottbus, Germany. She also studied landscape architecture at the Technical University of Dresden and specializes in landscape planning, land use, and water management, and their instrumentation in dealing with climate change. Her diploma thesis focused on regionally scaled strategies for rural land use and the sustainable development of the cultural landscapes in a commune in Switzerland. She taught the “cultural landscapes and historical gardens” module on the World Heritage master’s program for 3 years. She currently teaches in the field of environmental planning in land use and water management, strategic environmental assessment and environmental impact assessment, and city ecology at the Brandenburg University of Technology Cottbus-Senftenberg. She has also worked as a visiting lecturer on the master’s program for environmental and applied science at Halmstad University, Sweden. She has seven publications in different international journals, conference proceedings, and books. She has also gained scientific research and field study experience in Germany, Canada, the United States, Great Britain, Sweden, and Switzerland.

**Albrecht Gnauck** (Dr. rer. Nat. habil.) is a professor of ecosystems and environmental informatics at Brandenburg University of Technology at Cottbus, Germany. He has published several popular books on modeling and simulation and more than 300 articles in journals and books. His research focuses on water quality, the simulation and modeling of ecosystems, eutrophication models of lakes and rivers, including sediment/water interactions; the monitoring and modeling of point and nonpoint river pollution, time series analysis of water quality data, informatics tools for ecological modeling; and ecosystem management, including decision support systems for river basin management as well as new mathematical approaches to ecosystem theory. He has international research experience in European countries (the Czech Republic, Hungary, Italy, Poland, Russia, and the United Kingdom) and Asian countries (Bangladesh and Vietnam). He is a member of the Board of Directors of the International Society for Environmental Protection, Vienna, and a member of the Editorial Board of the journal *Ecological Indicators*.

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