The imperative of climate action to promote and protect health in Asia

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Who is AASSA?

The Association of Academies and Societies of Sciences in Asia is a non-profit international organization with science, technology, and innovation (STI) interests. It consists of scientific and technological academies and societies in Asia and Oceania. It was launched in 2012 through the merger of two organizations, i.e., AASA (Association of Academies of Sciences in Asia, founded in 2000) and FASAS (Federation of Asian Societies and Academies of Sciences, founded in 1984). Its current members are 32 national academies and societies of sciences from 30 countries and one regional academy of engineering and technology. The principal objective of AASSA is to act as an organization in Asia and Oceania which plays a major role in the development of the region through science and technology. AASSA serves as a forum to discuss and provide advice on issues related to science and technology, research and development, and the application of sciences and technology for socio-economic development.

Vision

To promote initiatives, networking in Asian and Oceanian academies and societies of science to address global challenges through science and technology.

Mission

To strengthen the capacity of Asian and Oceanian academies and societies in their efforts to reduce hunger and poverty; to improve health & education; to combat against climate change through sustainable development, ensuring inclusivity and equitability. And to provide evidence-based science policy advice.

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Acronyms and abbreviations

AASSA	Association of Academies and Societies of Sciences in Asia
CC&H	Climate change and health
CO_2	Carbon dioxide
COVID-19	Coronavirus disease 2019
CVD	Cardiovascular disease
DALYs	Disease-adjusted life years
EASAC	European Academies' Science Advisory Council
EWE	Extreme weather event
FAO	Food and Agriculture Organization of the United Nations
GHG	Greenhouse gas (carbon dioxide, methane, water vapour, nitrogen oxides, etc.)
GIS	Geographic information system
IANAS	InterAmerican Network of Academies of Sciences
IAP	InterAcademy Partnership
IBS	Irritable bowel syndrome
IPCC	Intergovernmental Panel on Climate Change
KVMRT	Klang Valley Mass Rapid Transit system
MIROC	Model for Interdisciplinary Research on Climate
NAPA	National Adaptation Plan of Action
NASAC	Network of African Science Academies
NO_x	Nitrogen oxides
OECD	Organisation for Economic Co-operation and Development
$PM_{2.5}$, PM_{10}	Particulate matter having a diameter of less than 2.5 or 10 micrometres
PTSD	Post-traumatic stress disorder
RCP	Representative concentration pathway
SARS	Severe acute respiratory syndrome
SDG	Sustainable Development Goal
SIDS	Small Island Developing States
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change (1995)
VBD	Vector-borne disease
WHO	World Health Organization

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Foreword

The United Nations at its General Assembly in September 2015 adopted 'Good health and well-being' and 'Climate action' as the third and thirteenth of its 17 ambitious Sustainable Development Goals (SDGs)' to be achieved by 2030. Each of these two goals is, in itself, tremendously important for the well-being of humankind and for the future of our planet, respectively, and has attracted scientific, socio-economic, and political attention worldwide. Even though not complete enough, there is a large amount of scientific and technological information for these two fields separately.

However, these two goals are inseparably intertwined with each other. Climate change in general and its resulting extreme weather events are already adversely affecting human health and greatly increasing the global burden of diseases. But, in terms of understanding the causal relationship between climate change and health, the scientific evidence base is neither sufficient nor coherent. Overcoming this knowledge gap requires truly multi- and transdisciplinary approaches engaging science, technology, social sciences, and the humanities. It also demands truly global-scale cooperation and collaboration using collective intelligence from all sectors of learned societies epitomized by national academies, and regional and global associations of them.

Recognizing this, the InterAcademy Partnership (IAP) launched an ambitious project called 'Climate Change and Health' with funding generously provided by the German Government. The project was spearheaded by the European Academies' Science Advisory Council (EASAC) and later joined by the Association of Academies and Societies of Sciences in Asia (AASSA), the Inter-American Network of Academies of Sciences (IANAS), and the Network of African Science Academies (NASAC). The contents and framework of the regional reports were decided at the kick-off meeting of the Working Group held from 3 to 5 November 2019 at the German National Academy of Sciences Leopoldina in Halle (Saale).

AASSA constituted a Working Group of nine experts nominated by its member academies. Later, more national representatives and young scientists nominated by the other AASSA member academies and the Global Young Academy, respectively, joined the Working Group. After one in-person meeting of the Working Group held from 24 to 25 February 2020 in Kuala Lumpur, Malaysia, a series of webinars, and numerous communications through electronic media among the Working Group members, the first draft report was completed in March 2021. The draft then was evaluated by peer-reviewers with wide experience and expertise chosen from inside and outside Asia and the Pacific region. The final draft, which accommodated comments, corrections, additions, and suggestions, was completed in June 2021 and sent to the member academies for their endorsement. As of the publication date (October 2021), most of the member academies had endorsed the final report, thus making it an official AASSA document.

At this juncture, I express my heartfelt gratitude to those who made this report possible. First and foremost, I thank Professor Volker ter Meulen, Past President of the IAP, for his vision, commitment, and leadership. It is he who secured the necessary funding and took control of the whole project. My thanks also go to Professor Khairul Anuar bin Abdullah, President of AASSA and AASSA's project leader on climate change and health, and his Malaysian support team for their enthusiasm and dedication towards this project. Special thanks are also due to the members of the Working Group and the peer-reviewers for their time and effort dedicated to this project.

Finally, I thank the member academies of AASSA, especially the Academy of Sciences Malaysia and the Korean Academy of Science and Technology, for their help and interest in this project.

Professor Yoo Hang Kim
Past President, AASSA

Summary

Climate change poses a significant threat to human health. Asia and Oceania, which experiences the full range of global climate variations – from deserts to lush forests, from the highest mountain in the world to the lowest depths of the ocean – have been identified as one of the most vulnerable regions in the world to the effects of climate change. With the progression of global warming, hazards due to severe heat spells and heavy rainfall have been predicted to increase further, which thus pose an inevitable threat to human health.

Climate change is already contributing to the burden of disease and premature mortality. A significant proportion of the population in Asia and Oceania is poor, vulnerable, and exposed to various health risks both directly through heat stress or infections and indirectly through disasters and other events related to climate change.

A range of environmental factors have direct and indirect effects on human health: the availability of clean air, potable water, safe food, exposure to hazards, pathogens and toxins, as well as several social, behavioural, and genetic factors determine the health and well-being of individuals and communities. Scientific and governmental organizations in this region have continued to explore the current and potential threats of climate change to human health.

On the basis of the evidence that has been gathered, there is a need for further exploration of the topic, to ensure that adequate and timely strategies are used to prevent and mitigate the effects of climate change on human health.

The COVID-19 pandemic has exposed the underlying vulnerability of this region to common diseases and their subsequent dire effects including deaths. The region now has no national boundaries in a rhetorical way. It thus opens up the debate on 'what is the common resource?', which is now not just limited to fixed assets but also to varying socio-economic processes that affect livelihoods, vulnerability, and resilience, such as global aviation, economic and industrial processes.

Some of the common challenges in Asia and Oceania include the following:

(1) the degree of public awareness;
(2) insufficient studies and research detailing particular aspects of this problem;
(3) inadequate data and limited access to those who require it;
(4) limited health-care facilities and resources;
(5) inconsistent government support and political interest;
(6) insufficient financial and economic support;
(7) the impact of high financial and disease burdens especially on the poor.

The evidence reveals that there is insufficient awareness that climate change is affecting human health through various pathways. In particular, the evidence on indirect health effects is limited. There is a need for real-time and accurate data across Asia and Oceania, which requires the collection of both primary and secondary data and models with an appropriate feedback system. A well-rounded understanding of the health effects of climate change, both direct and indirect effects, is crucial. This report recommends a multi-sectorial framework to embrace a coherent approach. The health sector should be an active participant in discussions, action planning, and implementation on climate change issues in collaboration with other economic areas and activities.

Although the climate change issue has been highlighted to a sizeable extent, its impact on health has not received appreciable attention from the world community. The role of AASSA is particularly important in addressing the spatio-temporal, socio-economic, and political variations within Asia and Oceania.

Areas lacking technological advancement and development require a different set of criteria and approaches to assess the health and well-being of their citizens, and AASSA can help to establish that for the region.

The main objectives of this report are the following:

(1) to emphasise that climate change is happening on a wide regional scale and escalating;
(2) to emphasize the significance of climate change effects on health through multiple pathways;
(3) to identify regional variations on impacts, solutions, science-based evidence, avenues for regional cooperation for mitigation, etc.;
(4) to fill knowledge gaps by suggested new research, increased transdisciplinary and inter-sectoral information sharing on the overlooked public health issues associated with climate change;
(5) to accumulate and use the evidence on the health impacts of climate change from the reports to emphasize the basis for coherent health policy development for climate change mitigation and adaptation strategies;
(6) to increase responsiveness to the health impacts of climate change as well as promoting actions that improve health while reducing greenhouse gas emission;
(7) to clarify the public health issues associated with climate change that should be addressed through multilateral collaboration;
(8) to highlight the common needs for national planning, for example public awareness, development of health-care facilities, education and training, research and knowledge implementation, financial resources, and government support in policy development.

1 Introduction

Overview

1. Human health has been improving until recently. This improvement, and with it an increase in life expectancy, is being tested during the current COVID-19 pandemic when many natural systems are degrading at unparalleled rates. There may be various explanations for this paradox to human health. One of them is climate change.
2. The pace and extent of recent environmental change suggest that it will not be possible to continue to exploit nature according to the same developmental and behavioural pattern to provide for a growing population.
3. This special report has been prepared in consultation with a group of experts nominated by their national science academies in the Association of Academies and Societies of Sciences in Asia (AASSA). Details of the Working Group responsible for preparing and compiling this report are given in Appendix 1.
4. Fifteen national academies participated in this project representing seven regions of Asia and Oceania: China, Japan, and Korea (East Asia); Armenia and Azerbaijan (West Asia); India, Nepal, Pakistan, and Bangladesh (South Asia); Malaysia and Indonesia (Southeast Asia); Russian Federation Far East (North Asia); Turkey (Middle East Asia); Australia and New Zealand (Oceania).

1.1 Sustainable development, climate change, and health

One of the biggest challenges in Asia and Oceania is to manage both development and health risks simultaneously. Sustainable development, which aims to make it possible to meet the needs of future generations along with the needs of the current population, was introduced to the world agenda by the United Nations in the late 20th century.

However, sustainable development, climate change, and health are interrelated. While Sustainable Development Goals (SDGs) clearly link health, climate change, and sustainable development, their applications are not integrated at the local level.

Goal 13 from the 17 SDGs is to take urgent action to combat climate change and its impact. Nations must address climate change impacts, confronting them to maintain their sustainable development in terms of economic and social systems. Efforts to redress climate change, through adaptation and mitigation, will similarly inform and shape the global development agenda. Poor and developing countries, particularly the least developed countries, will be among those most adversely affected and the least able to cope with the anticipated shocks to their social, economic, and natural systems (United Nations Department of Economic and Social Affairs 2020).

It is expected that climate and environmental change will hamper or even exacerbate poverty in some or all of its dimensions. Climate change is expected to affect opportunities for people to sustain livelihoods and generate income. These changes, combined with deficiencies in coping strategies and innovation in adapting to climate change threats, will probably lead to increased economic and social vulnerabilities of households and communities, especially among the poorest (Szabo *et al*. 2016).

Climate change and unsustainable economic and social development will finally take their tolls on human health, in the form of morbidity and mortality from communicable and non-communicable diseases as well as other indirect effects.

According to the World Health Organization (WHO), 13.7 million deaths (24% of all deaths) were attributed to environmental factors in 2016. Climate change is related to many of the environmental factors that cause the burden of diseases.

As a result of global warming and its other components affecting human health, studies on this subject have accelerated. In this context, the WHO declared the 2008 World Health Day theme as the effects of global warming and climate change on health and to create awareness in this regard (TÜBA 2010).

The United Nations (UN) Climate Change Conference held in Madrid, Spain, in December 2019 (COP25) had a major goal of reducing GHG emissions and helping countries facing severe effects of climate change. The occasion was used by the WHO to share the results of its first-ever survey of health and climate change, 'The WHO Health and Climate Change Survey: Tackling Global Progress', emphasizing the neglected link between climate change and health (CC&H). The report highlighted that the rising global temperature was seriously affecting the social and environmental determinants of health, and that there was an increase in the global burden of disease due to polluted air, polluted drinking water, food insecurity, etc.

1.2 Managing the global commons: what are the prospects for climate change and health?

Climate change is a global issue which affects every nation and all populations across the world. Managing climate change calls for managing the global commons which include shared natural resources found in the Earth's oceans, land, and atmosphere. Of particular concern is the shift of over-dependence on fossil fuels to renewable energy while adopting more energy-efficient transportation and industrial processes.

Nations need to come together in addressing these common goals. The ultimate goal in managing our global commons and climate change is to mitigate the resulting health impacts.

According to the 5th evaluation report of the Intergovernmental Panel on Climate Change (IPCC), the global average temperature has continuously increased since the 19th century (IPCC 2013). In response to this global threat, 196 countries committed to the Paris Climate Accord in 2015 (the Paris Agreement). It was a monumental initiative in laying out the global roadmap to keep global warming within 2 °C of pre-industrial levels, and preferably limit the increase to 1.5 °C (UNFCCC 2015).

Introduced in the same year, the SDGs expounded on the priorities the global community aspires to achieve by 2030 (UN 2015). Goals enshrined under the SDGs are either implicitly or explicitly linked with the Paris Climate Accord, as an overarching initiative for sustainable development. All the SDGs are directly or indirectly linked to produce synergistic effects and the emphasis is to consider health in all policies.

To address these changes, apart from achieving the Paris Climate Accord, which will keep the global average temperature rise below 1.5 °C by the end of 2030, it is essential to optimize the existing economic and social system and to establish a new one. This is not merely to cut GHG emissions but also to slow down climate change for nations, local governments, and business communities (Science Council of Japan 2019).

Many countries in Asia and Oceania have initiated plans to mitigate the environmental effects of climate change. These plans are implemented in consonance with development goals. Among the initiatives is the establishment of a National Action Plan on Climate Change to implement local adaptation plans to promote sustainable development through effective adaptation strategies.

1.3 The role of the AASSA report in addressing scientific and societal aspects for Asia and Oceania

The role of AASSA becomes highly significant in dealing with new and emerging health issues and challenges in Asia and Oceania in the face of climate change. While the world may face common challenges, a common solution or 'one size fits all' solution may not solve the complex problems that people face in different socio-economic and political systems.

For example, although the WHO managed to produce a global picture for COVID-19, significant gaps were noted by local practitioners and scientists in Asian countries which may lack sufficient financial and human resources.

Therefore, it is essential that local variations be tapped through detailed regional work that is possible through AASSA. Apart from varying levels of economic and financial challenges, Asia also has varied socio-political systems that present different challenges in terms of data collection, sharing, and representation in a similar fashion. At the same time, however, it is essential to capture this variety to understand the complexity of issues and report them effectively.

This AASSA report can be effective in bringing out these variations and implications for managing CC&H in the region. Besides, areas lacking technological advancement and development require a different set of criteria and approaches to assess patients and their well-being. AASSA can help identify and enlist such criteria for the Asia region.

2 Efforts in climate change and health in Asia

Overview

1. The impact of climate change not only affects human health but also causes significant reduction in productivity in general. Developing countries will be affected more than developed countries.

2. The diversity of the geographical and policy scope across the Asian and Oceania region is highlighted together with its climate change projections.

2.1 Previous AASSA academy publications on climate change and health

In some countries from Asia and Oceania, there has been no official academy work on climate change and health (CC&H) because of limited research on the impending impacts on human health.

However, there are several papers on the issue, published by various academy institutions. Furthermore, a good start has been made and more research will be forthcoming from universities and scientific societies across these nations.

On the contrary, some governments, as well as public and private national and international organizations, have published numerous studies on the impacts of climate change that directly and indirectly affect human health. Publications on CC&H are varied and focus on regions, cities, or specific groups of people or diseases.

For this report, 16 previous major publications from some of the member countries have been selected to represent AASSA on the Issue of CC&H. The list is shown in Table 2.1.

2.2 Geographical and policy scope

Asia and Oceania is considered to be the most vulnerable continent to climate change, and the most disaster-prone area in the world. The vast diversity of its topography and geography poses multiple threats to human society and the environment. Although climate change is a global issue, its health effects and vulnerability are likely to be substantially heterogeneous across regions, countries, and areas. The region's vulnerability is due to many and sometimes unique reasons:

(1) it is an area in the world with the highest population and has countries with the highest population density;
(2) it has some of the longest stretches of coastal areas;
(3) it is home to some of the most densely populated cities;
(4) it is dependent on an agriculture-based economy, which in turn is dependent on monsoon winds carrying seasonal rains.

Since 2000, 1.2 billion people have been exposed to hydro-meteorological hazards alone through 1,215 disaster events. These accounted for 91%, 92%, and 66% of global human exposures to tropical cyclones, floods, and landslides, respectively, on a per head basis. Almost 2 million people were killed in disasters between 1970 and 2011, representing 75% of all disaster fatalities globally. Between 1970 and 2010, the population exposed to flooding risk doubled from 29.5 million to 63.8 million, while those residing in cyclone-prone areas grew from 71.8 million to 120.7 million (ESCAP 2012).

The current population of Asia and Oceania is 4.6 billion people, equivalent to 60% of the world's population. The population density is 150 per square kilometre (387 people per square mile). The total land area is 31,033,131 km^2 (11,981,954 square

Table 2.1 A sample of previous academy work on CC&H in Asia and Oceania

No.	Publication/academy source	Published output
1	*The Lancet Public Health*, 2021	The 2020 China report of the *Lancet* Countdown on health and climate change
2	Ministry of Environment; Ministry of Education, Culture, Sports, Science and Technology; Ministry of Agriculture, Forestry and Fisheries; Ministry of Land, Infrastructure, Transport and Tourism; Japan Meteorological Agency, 2018	Synthesis report on 'Observations, Projections and Impact Assessments of Climate Change in Japan and its Impacts'
3	Proceedings of an International Symposium on '*One Green Asia*' by the Korean Academy of Sciences and Technology, 2010	Towards greener Asia: Poverty reduction helps in conservation and sustainable use of biodiversity
4	*Journal of Advance Research in Dynamical & Control Systems*, 2018	Special issue on 'National Security and the Social – Economic, Ecological Position in the Russia Federation Far Eastern Region'
5	*International Journal of Development and Sustainability*, 2017	The role of economic and social instruments of environmental policy in Azerbaijan
6	Publication by National Communications of Armenia under the UN Framework Convention on Climate Change (1998, 2010, 2015, 2020)	Distribution of heatwaves in several cities and urban places of Armenia, hygienic evaluation of changeability
7	Report prepared by the Ministry of Environment and Urbanization and published by the Turkish Academy of Sciences, 2019	The Climate Change Education Modules Series which includes the issue of the impact of climate change on human health
8	AASSA, Pakistan Academy of Sciences, InterAcademy Partnership, 2016	Proceedings of AASSA Regional Workshop on 'Challenges in Water Security to meet the Growing Food Requirements' Proceedings of AASSA Regional Workshop on 'Challenges in Water Security to meet the Growing Food Requirements'
9	AASSA, Far Eastern Branch of the Russian Academy of Sciences	The 3rd AASSA Workshop on 'Impacts and Mitigation of Climate Change in Asia and Oceania'
10	AASSA, Innovative Water Center (Cambodia)	The 7th AASSA Regional Workshop on 'Sustainable Development Goal of Water and Sanitation after MDGs (Millennium Development Goals)'
11	AASSA, Korean Academy of Science and Technology	AASSA International Symposium on 'Global Health Issues in Asia'
12	AASSA, Academy of Sciences Malaysia	AASSA-ASM Conference on 'Water-borne Infectious Diseases'
13	AASSA–FEB RAS	Regional Workshop on 'Climate Change Adaptation and Mitigation: Sustainable Agriculture and Health Security'
14	Regional Environment Change 13, 2013	Case study from Khumbu, Nepal, about climate-related hydrological change and human vulnerability in remote mountain regions
15	Climate Change Cell, Department of Environment, MoEF, Government of the People's Republic of Bangladesh.	CCC (2009) Climate change and health impact in Bangladesh
16	Department of Agriculture, Water and the Environment, Australian Government, 2019	Climate change impacts in Australia

miles). The urban population of the region is 50.9%. The median age is 32.0 years. Life expectancy for both sexes is 74.2 years (females, 76.4 years; males, 72.1 years). The relevant demographical data are shown in Table 2.2.

The variations in demography, topography, and geography of Asia and Oceania influence the climate change effects and health impacts on humans. These are summarized in Table 2.3. The effects of climate change on humans are elaborated further in chapter 3.

Table 2.2 The demography of Asia and Oceania in 2020 (Wikipedia, worldometer)

Demography / Country	Population (2020)	Density (population/km^2)	Land area (km^2)	Migrants (net)	Fertility rate	Median age	Urban population (%)
Armenia	2,963,243	104	29,743	–4,998	1.8	35	63
Australia	25,499,884	3	7,682,300	158,246	1.8	38	86
Azerbaijan	10,139,177	123	82,658	1,200	2.1	32	56
Bangladesh	164,689,383	1265	130,170	–369,501	2.1	28	39
China	1,439,323,776	153	9,388,211	–348,399	1.7	38	61
India	1,380,004,385	464	2,973,190	–532,687	2.2	28	35
Indonesia	273,523,615	151	1,811,570	–98,955	2.3	30	56
Japan	126,476,461	347	364,555	71,560	1.4	48	92
Malaysia	32,265,999	99	328,550	50,000	2.0	30	78
Nepal	29,136,808	203	143,350	41,710	1.9	25	21
New Zealand	4,822,233	18	263,310	14,881	1.9	38	87
Pakistan	220,892,340	287	770,880	–233,379	3.6	23	35
Republic of Korea	51,269,185	527	97,230	11,731	1.1	44	82
Russian Federation	145,934,462	9	16,376,870	182,456	1.8	40	74
Turkey	84,339,067	110	769,630	283,922	2.1	32	76

2.2.1 Global context

Table 2.3 The climate change effects and health impacts in Asia and Oceania

Country	Geography/topography	Climate change effects	Health impacts
Armenia	Mountainous country with fast-flowing rivers and few forest, arid climatic conditions Highly susceptible across entire territory Vulnerable ecosystems	Increase in air temperature Decrease in precipitation Increase in frequency and intensity of extreme weather events (drought, heatwave, frost, hail, strong winds, precipitation) and natural disasters (flood, inundation, forest fire)	Increase in heat-related deaths Increase in cardiovascular diseases
Australia	Wide variety of landscape: tropical rainforest, mountain, desert, semi-arid land (outback) Driest inhabited continent; extreme weather fluctuations	Increase in bushfires Increase in extreme weather events (drought, heatwaves) by 46% from 2007 to 2016 Destroy crop production Increase allergies caused by pollen Amplify the risk of mosquito-borne diseases	Increase in heat-related diseases Worsening existing health issues: respiratory, heart, brain, diabetes-related conditions Exacerbates pre-existing heart failure and kidney diseases

Continues

Table 2.3 (*continued*)

Country	Geography/topography	Climate change effects	Health impacts
Azerbaijan	Various landscapes: from wetlands to high mountains, deserts to fertile valleys, mountain ridges, crests, yailas[1], plateaus Terrain consists of plains and lowlands Highest point: Bazarduzu Dagi mountain (4,467 m); lowest point: in the Caspian Sea (–28 m) Climate influenced by cold Arctic air, temperate air masses of Siberian anticyclone Greater Caucasus protect from direct influence of cold air from the north, leading to subtropical climate on most foothills and plains Plains and foothills are characterized by high solar radiation	Ninety per cent of the cause associated with human-made pollution Increase in intensity and frequency of storms and blizzards Extreme weather events (rising sea and ocean levels, storms, hurricanes, torrential rain, severe heat, drought, warm winds) and natural disasters (flood, etc.) Deterioration of living conditions Spread of water- and vector-borne diseases	Increase in health-related issues Decrease in availability of clean drinking water Increase in poverty, hunger, and food insecurity
Bangladesh	Divided by three regions: fertile Ganges–Brahmaputra–Meghna delta, which covers around 80% of the country; Madhupur and Barind plateaus; and evergreen hill ranges along the eastern and northeastern parts Tropical country with deltaic floodplain	Increase in sea level Increase in temperature Increase in precipitation during monsoon and decrease in dry season Increase in frequency of climate-sensitive natural disasters, especially floods and cyclones Salinity intrusion along the southern part, severely along the southwestern parts	Increase in water-borne diseases Increase in vector-borne diseases Increase in heatstroke and respiratory illness
China	The world's third largest country by area and its most populous Terrain is high in the west and low in the east with 67% as mountain, plateau, and hill, and 33% as basin and plain Has 23 provinces, 5 autonomous regions, 4 municipalities under central government, and 2 special administrative regions	Increase in extreme natural disaster (heatwaves, storms, floods, drought) Deteriorating water and air pollution Mostly meteorological (drought, floods, typhoons, cold waves) and geological disasters (tsunamis, earthquakes, landslides, mud-rock flows, land subsidence)	Increase in temperature-related mortality Increase in morbidity for temperature-related cardiovascular and cerebrovascular diseases. Increase in vector-borne diseases

Continues

[1] Enormous regeneration potential, impenetrable jungles, and swamps.

Table 2.3 (*continued*)

Country	Geography/topography	Climate change effects	Health impacts
India	Its subcontinents lying atop the Indian tectonic plate, part of the Indo-Australian Plate[2] The world's second most populous country Diverse geography ranging from glaciers to deserts to coasts and tropical forests	Reduction in agriculture productivity (wheat and rice) in the Indo-Gangetic plain due to monsoon disturbances and changing temperatures Increase in frequency and intensity of extreme weather events (heatwaves, cyclones, unpredictable monsoons resulting in floods and droughts) Ongoing and impending water shortage crisis Air pollution crisis in all major cities Crisis from human migration	Increase in malnutrition and associated physical and mental diseases Increase in severe child stunting Increase in pathogen and parasites associated with water-borne diseases Urban health crisis and mental disease associated with loss of livelihood, migration, and densely populated cities Increase in malnutrition, infectious and respiratory disease burden
Indonesia	The largest archipelagic country in the world Two seasons: wet and dry with no extremes of summer or winter Dominated by the tropical rainforest climate; highly unstable tectonically, lies on the Pacific Ring of Fire[3]; has the world's highest levels of biodiversity	Increase in precipitation Increase in air pollution Changing patterns of wet and dry seasons; increase in wildfires Rising sea level	Increase in vector-borne diseases Increase in water-borne diseases Increase in heat-related diseases
Japan	Densely populated and urbanized; three-quarters of the country's terrain is mountainous Population 126.2 million, concentrated on narrow coastal plains Terrain ranging from coastal areas of the south to the glaciated mountains of the north Its landscapes vary from plains to deserts, forests, hills and plateaus	Increase in extreme weather events (heavy rain, typhoons, storm surges, floods, sharp temperature rises) Increase in infectious-related bacteria broadens the geographical distribution of vector organisms with longer active periods Rising ambient temperature	Increase in heat-related deaths and heatstroke Decline in sleep quality, tiredness/fatigue Negative impacts on work efficiency, education, and learning effectiveness
Malaysia	Within the equatorial region where a tropical rainforest climate is apparent all year round Two parts to Malaysia (Peninsular and East Malaysia), separated by the South China Sea, feature coastal plains rising to hills and mountains High in humidity	Increase in sea levels Increase in rainfall and flood risks Increase in droughts	Increase in heat-related diseases Increase in vector-borne diseases

Continues

[2] The Indo-Australian Plate is a major tectonic plate that includes the continent of Australia and surrounding ocean, and extends northwest to include the Indian subcontinent and adjacent waters. It was formed by fusion of the Indian and Australian plates approximately 43 million years ago when the mid-ocean ridge in the Indian Ocean, which separated the two plates, ceased spreading.

[3] The Ring of Fire (also known as the Rim of Fire or the Circum-Pacific Belt) is a major area in the basin of the Pacific Ocean where many earthquakes and volcanic eruptions occur.

Table 2.3 (*continued*)

Country	Geography/topography	Climate change effects	Health impacts
Nepal	Highly variable topography Lies in the Himalayan–Hindu Kush mountain range and the Tibetan Plateau[4] Divided into three principal physiographical belts	Increase in extreme weather events Increase in water and vector-borne disease Increase in warmer days, nights, and warm spell durations	Increase in malnutrition Increase water- and vector-borne diseases in mountain regions Increase in cardio-respiratory diseases Increase in psychological stress Increase in heat-related issues and injuries due to global warming
New Zealand	Elongated, mountainous, lies approximately at a right angle to the prevailing westerly winds Located near the centre of the water hemisphere and made up of two main islands: North and South	Increase in average air and sea temperatures Increase in frequency of drought, flood, precipitation Rising sea level Air pollution due to wildfires	Increase in heat-related mortality Increase in the number of diarrhoeal diseases Increase in hospitalization in dry area
Pakistan	Thirty-third largest country by area, located in South Asia with a coastline of 1,146 km Extremely diverse with four major provinces apart from northern areas Three major areas: the northern highlands[5], the Indus River plain, and the Balochistan plateau	Climate varies from tropical to temperate with arid conditions in the coastal south, monsoon season Increase in melting glaciers[6] Erratic weather pattern[7] Desertification of fertile cultivable land Heatwaves and natural fires Reduced water flow[8] Floods, landslides, and drought leading to food insecurity	Stunted growth due to malnutrition Spread of water- and vector-borne diseases Increase in chronic diseases Increase in mental health problems
Republic of Korea	Can be divided into four general regions: eastern (high mountain ranges and narrow coastal plains); western (broad coastal plains, river basins and rolling hills); southwestern (mountains and valleys); and southeastern (broad basin of Nakdong River) Mostly mountainous and not arable Lowlands (located primarily in the west and southeast) make up only 30% of total land area	Increase in particulate matter among air pollutants Increase in ozone concentration Increase in seawater temperature Increase in the amount of snow in the Northern Hemisphere Increase in allergy caused by pollen	Increase in heat-related diseases Declining immune system Increase in water-borne diseases

Continues

[4] Commonly referred to as 'the Third Pole' of the planet.
[5] The northern highlands contain the Karakoram, Hindu Kush, and Pamir mountain ranges which have some of the world's highest peaks including 5 of 14 'eight-thousands' (mountain peaks over 8,000 metres or 26,250 feet).
[6] More than 5,000 glaciers in the Himalayan range have been melting at a rate faster than ever in recorded history, posing a major threat to the country's water resources and causing a 60% shortage, affecting energy and agriculture security.
[7] Unseasonal rains, unpredictable flooding, droughts, intense heatwaves, varying temperature, saturation of lakes, storms, hurricanes, landslides, etc.
[8] Reduced flow of water in the Indus River over a period of 30 years has resulted in intrusion of the Arabian Sea into the Indus delta, affecting the life of nearly 2.5 million people who were dependent on fishing and agriculture.

Table 2.3 (*continued*)

Country	Geography/topography	Climate change effects	Health impacts
Russian Federation Far East	Eastern part of Russian Federation[9] has access to two oceans: the Pacific and the Arctic Vast differences in climatic conditions: from Arctic ice deserts in the north to subtropics in cedar–broadleaved forests in the south	Increase in air temperature Permafrost thawing of glaciers Drought in vast territories Rapid desertification of soils Flooding of the coasts of continents and islands Development of endemic diseases Deterioration of air quality Loss of natural humidity in forests Increase in the duration of the fire hazard season and the quantity of forest fires	Decrease in the level of public health Spreading of infectious diseases Increase in environmentally related diseases, the most notable being chronic obstructive lung diseases
Turkey	Surrounded by sea on three sides, extension of the mountains and the variety of landforms Divided into seven regions: Marmara; Aegean; Black Sea; Central, Eastern, and South-Eastern Anatolia; and The Mediterranean	Among subtropical and temperate zone Decrease in temperature at night	Increase in heat-related deaths Increase in chronic respiratory diseases Increase in vector-borne diseases

2.2.2 Framework of AASSA's inquiry

Asia and Oceania is different from many other parts of the world, which are planning various mitigation and adaptation strategies. Asia is also very diverse within itself: there are several landlocked nations, coastal countries, and countries with vast areas such as India and China with considerable diversity within them.

This AASSA report addresses this diversity within the region as well as the factors that are common to the region. There are many aspects of climate change that are of great importance to this region which may not be of such high priority in the others, such as the following.

(1) The lack of public understanding and education as well as the gap in capacity building for implementing mitigation strategies.

(2) Children in Asia and Oceania are highly vulnerable to extreme heat and food insecurity along with diseases such as malaria and diarrhoea. Besides, Asia and Oceania also has a high youth population.

(3) The differences in the adaptation of public health ethics or bioethics during outbreaks among nations in Asia and Oceania.

(4) The effects of climate change on natural disasters can cause a rise in humanitarian crises that demands enhanced preparedness of public health capacities.

In the following chapters, we highlight the latest scientific evidence, which will serve as a basis for crafting recommendations for relevant and timely policy options in mitigation and adaptation plans. Likewise, the report also identifies and summarizes research gaps that need to be addressed in future studies.

[9] The area of the region is 6.9429 million km^2 (about 42% of the territory of the Russian Federation); only 5.6% of the country's population, or slightly more than 8.2 million people, lives here.

3 Major health effects

Overview

1. Asia and Oceania is the most vulnerable region to climate change. Direct and indirect health effects are affecting most countries in it.

2. South Asia and East Asia are most vulnerable to floods and infectious diseases compared with the rest of Asia and Oceania.

3. Undernourishment and malnutrition are major threats, while West Asia and Russian Federation Far East have been struggling with agricultural issues.

4. Air pollution and allergies are closely linked. They are affecting most countries, particularly in urban areas.

5. Human fertility is another long-term impact of climate change and has been observed by Malaysian scientists.

6. Geography and topography, socio-economy, as well as age and health are the main factors contributing to vulnerability in populations and regions in Asia.

7. Forced migration, mental health, and stunting are other indirect health effects and occur mainly in West Asia, Turkey, and the Russian Federation Far East.

8. Tipping points and existence risks depend on climatic indicators and ecological indicators in mapping the future of the region.

9. Climate change effects will inevitably alter the current norms of development and its pathways towards sustainability and the well-being of society.

The Asia Pacific region is regarded as the most disaster-prone area of the world. Since 2000, 1.2 billion people have been exposed to hydrometeorological hazards alone through 1,215 disaster events. The impacts of climate change on meteorological phenomena and environmental consequences are well documented. Climate change is the net effect of global warming due to positive radiative forcing as a result of the accumulation of greenhouse gases (GHGs) in the atmosphere as well as global cooling due to negative radiative forcing from the accumulation of atmospheric aerosols from natural and human-made sources. Figure 3.1 shows the health impacts, environmental impacts, and environmental modifications related to climate change.

Climate change may leave numerous types of effect on human health. The increase in the extreme weather events (EWEs) is most likely to cause a huge number of injuries and death (Kabir *et al*. 2016). Several vector-borne diseases (VBDs) are worthy of mention and are considered in section 3.6.2.

3.1 Introduction to scope and scale

In the field of health, various aspects of the impact of climate change are considered: from direct exposure (total average temperature increase and change in rainfall, frequency and duration of heatwaves, frequency and duration of droughts and dry winds, frequency of extreme climatic manifestations) to indirect exposure (effects on carriers of infectious diseases, changing storage conditions and manufacturing of food products, etc.).

It is noted that climate change can influence human health both directly and indirectly (US Global Change Research Program 2016). In fact, climate change has been noted as the biggest health challenge of the 21st century, which can alter the situation attained through years of public health efforts (Prabhakaran and Reddy 2018).

This chapter will describe some of the major health effects in the Asia and Oceania

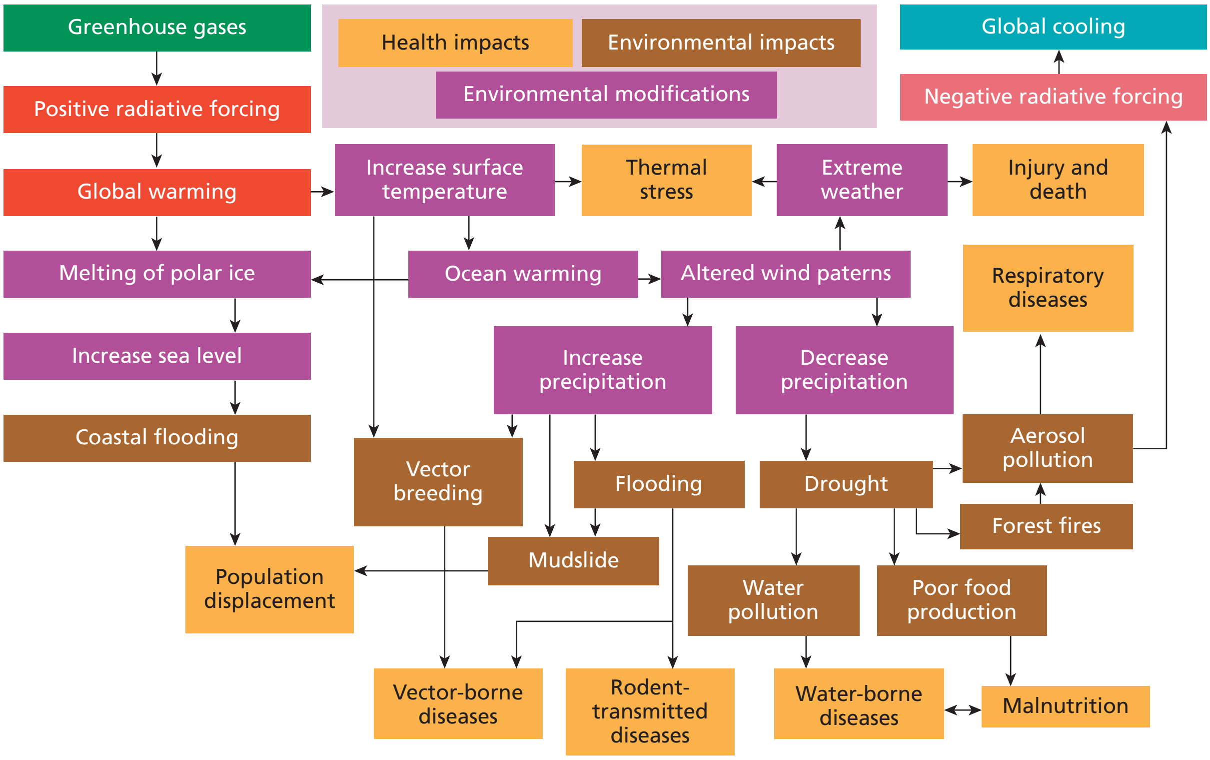

Figure 3.1 Health impacts, environmental impacts, and environmental modifications of global climate change (Hashim and Hashim 2016).

region. There are subtler health effects of climate change that have not been discussed extensively because of the lack of research and scientific evidence. Among these are the effects of climate change on mental health, human fertility, allergies, and forced migration (Figure 3.2)

In this chapter, we highlight these potential health effects which can have significant implications on public health locally and globally.

3.2 Direct heat-related health effects

In the context of human health, normal body temperature ranges from 36.1 to 37.8 °C. Heat is lost to and gained from the environment through radiation, convection, conduction, and evaporation of sweat. The personal factors that lead to the development of heat-related health effects are due to the inability of the body to balance between heat gains and heat losses (Matthies *et al*. 2008; McGregor and Vanos 2018).

Exposure to heat has emerged as a major public health concern in the time of climate change (Martiello and Giacchi 2010). The increase in environmental temperature leads to heat-related health effects. Heat-related effects are physiological insult to the body from exposure to heat overload, which can lead to an elevation of core body temperature that surpasses the compensatory limits of thermoregulation (Atha 2013). The symptoms of heat-related effects may include heat rash, heat cramps, heat syncope, heat exhaustion, heatstroke, and even death (McGregor *et al*. 2015; McGregor and Vanos 2018).

3.2.1 Human response to heat

Urban heat islands are a factor in many cities and have been particularly important contributors in some heatwave events (Kovats and Hajat 2008; Matthies *et al*. 2008). If GHG emissions continue at close to current levels, most people in cities around the world will suffer tremendously. It is well known that heat poses risks to occupational health and

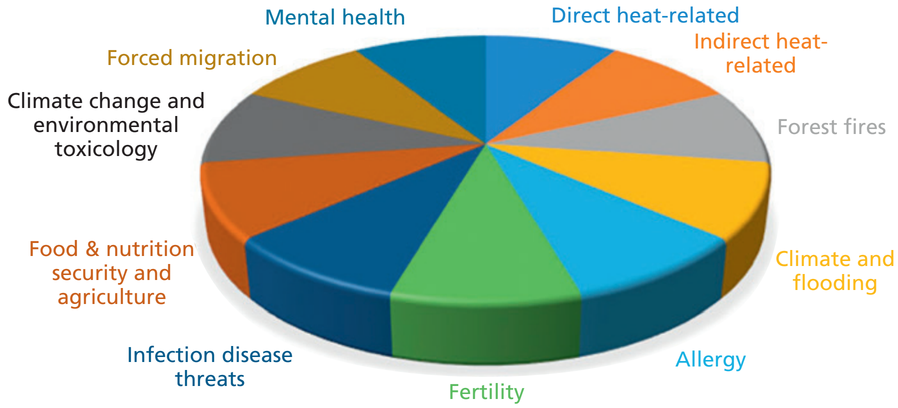

Figure 3.2 Major health effects in Asia and Oceania.

productivity, especially in outdoor settings in regions with high ambient temperatures.

Two studies have analysed the heatwave trends in Malaysia (Suparta and Yatim 2017; 2019). The analysis used the heat index in East Malaysia (Sabah and Sarawak) and showed that heatwaves increased from 2008 to 2010. However, the effect on human health was minimal. This might not be vital now, but the situation may change in the future.

Another study looking at the projection of average temperature during July over Peninsular Malaysia predicted that the temperature would rise from 26 °C in 1960 to around 29–30 °C at the end of the 21st century (Tangang *et al.* 2012).

The projected temperature rises from 28 °C in 2018 to 29–30 °C in 2100 may have less effect on heat-related health conditions. Nonetheless, there are still some factors other than the rise in temperature that need to be considered in predicting the impact of heat on the health of the population.

A prediction model has shown that many parts of New Zealand will experience more than 80 days per year above 25 °C, whereas currently most parts of the country typically see 20–40 days per year of such high temperatures. In Auckland and Christchurch, it has been estimated there are about 14 heat-related deaths each year when temperatures exceed 20 °C. This number is likely to rise more than sixfold if global average temperatures rise by 3 °C (IPCC AR4 2007).

In New Zealand, there are few studies of the health effects in the workplace, but exposure to heat is common. There are about 170,000 workers in agriculture, forestry, and fisheries, for example, these being prime examples of industries susceptible to heat stress.

Australia has 90% of its population living in urban areas with the corresponding risk of heat exposure from heat island effects in future years. The Heat Exposure Vulnerability Index for Australia for 1990–2017 is high and shows an upward trend in the years ahead. Furthermore, the nationally averaged Australian heatwave season (November–March) has accumulated an excess heat factor for the past 20 heatwave seasons (1999–2000 to 2018–2019).

Over the past 100 years, heatwaves have caused more loss of life in Australia than any other natural hazard. They exacerbate existing health issues such as respiratory and cardiovascular conditions, mental health, and diabetes, and may result in heat exhaustion or heatstroke. Heatwave-induced droughts destroy crop production while higher temperatures can increase allergies caused by pollen and amplify the risk of mosquito-borne diseases.

In 2013 and 2014, Australian businesses lost approximately 3 days of productivity each year from employee time to heatwaves, resulting

Table 3.1 Projected changes in heat-related mortality in Japan using the Model for Interdisciplinary Research on Climate (MIROC3.2_hires) with scenarios of different target stability levels (Project Team for S-4 Comprehensive Projection of Climate Change Impacts 2009)

	Heat-related mortality risk	450 Scenario hypothesis	Business as Usual (BaU)	Highest risk region
Current				Chugoku, Shikoku, Kyushu (southwest Japan)
Middle (2050s)	1.8	2.1	2.2	
End (2090s)	2.1	2.8	3.7	

in approximately EUR4.2 billion or 50 basis points of Australia's gross domestic product. Furthermore, according to the Australian Bureau of Statistics, 70% of Australian workers stated that they had worked less efficiently at some point in the year due to heat.

Currently, an increasing trend in heat-related deaths has been reported nationwide in Japan (Chung *et al*. 2015; Lim *et al*. 2016; Yamazaki and Michikawa 2017; Fujibe *et al*. 2018). The number of ambulance transports for patients with heatstroke has increased over recent decades (Ng *et al.* 2014). In the summer of 2018, ambulances transported more than 95,000 patients with heatstroke—a new record since 2009 when the Fire and Disaster Management Agency began their surveys. Populations aged 65 and older accounted for most of the ambulance-transported victims and heatstroke deaths, with some important observations: heatstroke symptoms often occurred at home and commonly in older adults (Kondo *et al.* 2013; Fire and Disaster Management Agency 2018).

In a multi-country study (including Japan and other Asian countries), the risk of heat-related death was found to be higher in early summer than in late summer (Gasparrini *et al*. 2016). The effect of low temperatures on mortality can be delayed for up to around 10 days, whereas the effect of high temperatures occurs within 1–2 days.

However, it has been reported that in Japan populations have become less vulnerable to heat stress over the past four decades (Onozuka and Hagihara 2015; Ng *et al.* 2016; Chung *et al*. 2018). For example, the association between temperature and mortality from 1972 to 2012 observed an upward shift in the threshold of heat-related mortality. The study also found that the risk of heat-related mortality (the relative risk for the 99th percentile of temperature against the threshold temperature) decreased from 1.18 to 1.01. A projection of changes in heat-related mortality risk have been made using scenarios with different target stability levels from the climate forecast information using the Model for Interdisciplinary Research on Climate (MIROC) dataset, as shown in Table 3.1.

A projection based on representative concentration pathway (RCP) 4.5 predicted that, by the end of the present century, the minimum wet-bulb globe temperature (WBGT) would rise in every region of Japan, and in the west of Tokyo there would be no days in August when it fell to 21 °C or below. A wet-bulb globe temperature value of 21 °C is stipulated as a the 'almost safe' level under the Japan Sports Association's 'Guidelines to how much exercise can be safely performed' (Suzuki-Parker and Kusaka 2015).

Daegu is the hottest city in Korea, but heat-related diseases are most common in Gyeonggi region because different regions in Korea have different resiliencies and vulnerabilities to temperature, health conditions, and social adaptability. Korea also has a different definition of heatwaves[10]

[10] The criteria for defining heatwave vary from region to region in Korea. Heatwave is defined by a combination of apparent temperature considering the highest temperature, average temperature, wind and humidity, temperature indicators (e.g. heat index), intensity (absolute temperature and temperature percentile), and the heatwave's duration.

(Korea Centre for Disease Control and Prevention 2018).

A rise in temperature of 1 °C caused the risk of death to increase for chronic illnesses such as cardiovascular diseases (CVDs; 6%), cerebrovascular diseases (4%), and respiratory diseases (2%).

In addition, heatwave is more intense if it lasts longer and, if it comes earlier than usual, the mortality rate will escalate (Son *et al*. 2012; Na *et al*. 2013; Benmarhnia *et al*. 2015).

China's warming rate is higher than the global average, with the national average being 0.24 °C per decade (Centre for Climate Change of the China Meteorological Administration, 2018). China's countrywide population-weighted temperature has risen by 0.64 °C from the 1986–2005 baseline to 2019 (Cai *et al*. 2021). Extreme high temperature leads to classic direct heat-related illnesses such as heat cramps, heat syncope, heat exhaustion, and heatstroke. Chronic diseases such as CVD, respiratory disease, and kidney disease are also related to extreme heat.

In 2019, the number of heatwave-related mortalities in China was about 26,800, while the number of high-temperature-related mortalities reached 97,900 (Cai *et al*. 2021). The annual average of these two types of heat-related mortality during 2015–2019 was about 2.4 and 1.6 times those during 1990–1994, respectively. East and South Central China suffered from a greater mortality burden caused by heat (Cai *et al*. 2021).

If the global warming increased from 1.5 °C to 2 °C, there would be more than 27,900 additional heat-related deaths annually out of 831 million urban inhabitants in China, even if improved adaptation capacity is considered (Wang *et al.* 2019).

Besides, many empirical studies have revealed how heat affects specific types of disease in China. The heatwave was identified as being associated with 2%, 8%, and 6% increases in total, cardiovascular, and respiratory hospital admissions in Shanghai between 2005 and 2008 (Ma *et al.* 2011). The evidence from 8 million hospitalized patients in China showed that the rapid changes in short-term temperature increased hospitalization rates for CVD and cerebrovascular diseases (Tian *et al.* 2019). With a 1 °C increase in the daily range of the temperature, hospitalization rates for digestive system disease in the elderly would increase by 2.14% (Wang *et al.* 2019). A positive correlation between temperature and childhood asthma was founded from research in 43 cities in China (Zhang *et al.* 2016).

Most of the studies in Armenia that examined the impact of climate change on population health reported that most deaths due to heatwaves were caused by exacerbation of chronic diseases. Most of the mortality was from CVD. There was also an increase in mortality from respiratory diseases, metabolic and endocrine disorders, and tumours.

Results show that the maximum thresholds of air temperature, which can be observed only during the hottest period of the year, are more important in terms of the impact of anomalous climatic conditions on population health indicators. In July–August, when the air temperature is the highest and heatwaves very frequent, there is a significant increase in the number of deaths from all causes, including accidents, injuries, and poisoning. In addition, each additional day of heatwave can cause five additional deaths, including one accident.

Over the past few decades, Nepal's temperature has been warming by about 0.6 °C per decade and, according to the Nepal National Adaptation Plan of Action (NAPA) to climate change formulated in 2010, it is expected to increase by 1.4 °C, 2.8 °C, and 4.7 °C by 2030, 2060, and 2090 respectively. Furthermore, by 2060, in the summer season, the frequency of hot days and nights will increase by 15–55% and 6–77%, respectively.

In 2013, Pradhan *et al*. investigated climate-change-related heat-stress responses in two districts, Bara and Parsa in the Terai region of Nepal, and found that average temperatures had been increasing in the study regions, along with mortality rates due to heat stress. The study found that farmers and outdoor workers who were most vulnerable to heat-related impacts did not have effective coping strategies or proper awareness about potential health issues, and suggested that it was imperative to perform more research in this area, so the government could introduce timely and effective strategies such as protective equipment, training on acclimatization methods, temperature maintenance devices, etc. (Pradhan *et al.* 2013).

Among very few published papers on this topic, Budhathoki and Zander (2019) is most recent. It explored socio-economic impacts associated with EWEs in the terai regions. Their survey of 350 farms found that 84% of farmers self-reported moderate or severe heat stress, and 85% reported moderate or severe cold stress, during 2012–2017. Furthermore, the farmers reported that EWEs had compromised their labour productivity. Like the study of Pradhan *et al*. (2013), it recommended 'community-based education and engagement' programmes to 'facilitate proactive adaptation' (Budhathoki and Zander 2019).

The literature suggests that heat-related impacts on health are multifold as they affect different age and occupation demographics in multiple ways. Policies for adaptation need to take into account this dynamism on drafting as well as implementation.

Meanwhile, heatwaves have significantly increased in terms of their frequency, intensity, and duration in India over the years from 1985 to 2009 compared with 1960 to 1985 (Watts *et al*. 2017). Burke (2010) noted that 2010 was the hottest summer ever recorded, which led to many hospitalizations due to heatstroke. Guleria and Gupta (2016) noted the consistent increase in the number of heatwaves per decade, from fewer than 500 up to 1990, to nearly 580 (1991–2000) and about 670 (2000–2010). The numbers are likely to increase in the future. There are serious health consequences of heatwaves, which have taken more than 22,000 lives in India since 1992.

There is a paucity of formal studies focused on the increase of heatwaves in Bangladesh, but the increasing trend of temperature has been established in several recent studies. Rahman (2008) reported that the health impacts associated with heatwaves are heatstroke, dehydration, and aggravation of CVD. In the recent past, it was also observed that the prevalence of diarrhoeal diseases increased during extreme temperatures and heatwaves, particularly among young children (Borroto 1998).

Heat-related morbidity and mortality are major concerns for megacities such as Dhaka (Kovats and Akhtar 2008). Studies have shown that temperature increases are likely to lead to multiple negative health consequences among the exposed population (Ciais *et al*. 2013). EWEs such as drought have been found to lead to higher incidences of dysentery and diarrhoea due to the use of contaminated water because most of the water sources dry out. Those who live in urban areas are more vulnerable than those who live in rural areas.

Major cities such as Dhaka, Chittagong, and Khulna will be adversely affected by such weather-related extremes (Alam and Rabbani 2007).

In Turkey, the effect of heatwaves in cities depends on the level of exposure to hot air (frequency, degree, and duration), the density of the population, and the sensitivity of the population. The direct effects appear as sunburn, heat cramp, heat fatigue, heatstroke, or sunstroke. It can lead to worsening of health or even death depending on the person's health.

Owing to the climate zone in which Turkey is located, the probability of seeing hot air waves is very high. In this respect, the southeastern Anatolia region is at a higher risk than the Marmara region. However, since the

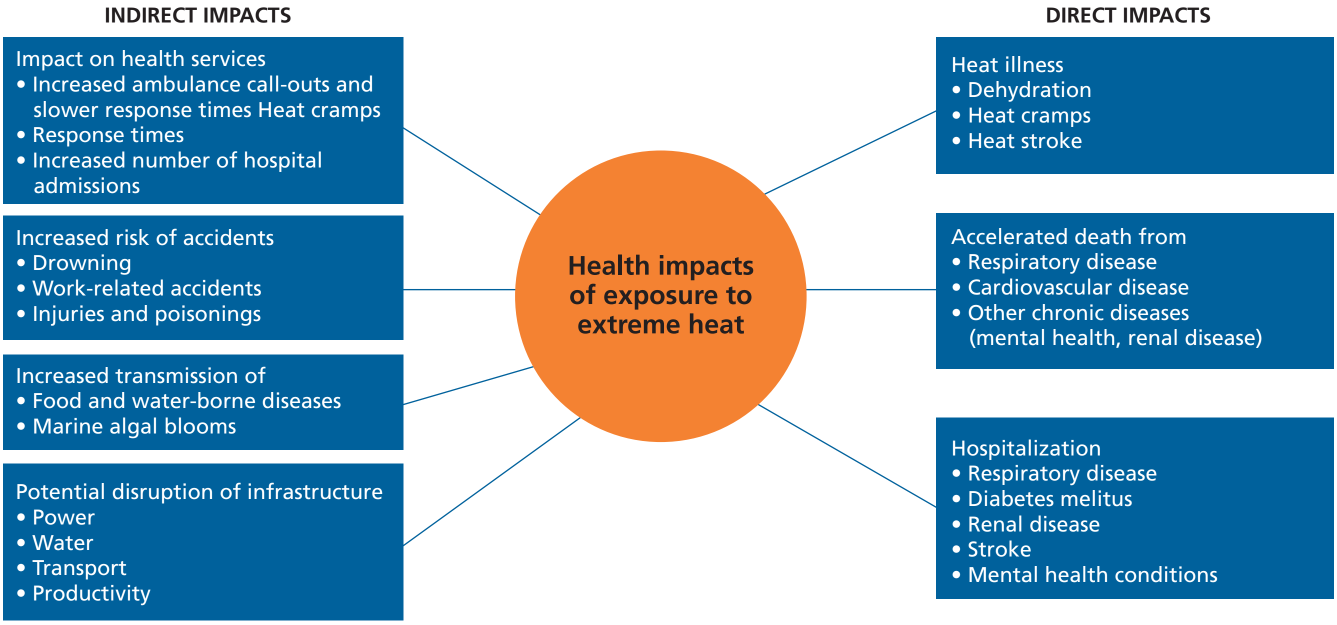

Figure 3.3 The impact of exposure to extreme heat on human health.

population of the Marmara region is denser, it is likely that the effects of hot air waves are higher (SB 2015).

Heatwave episodes are a more common issue in Asia and Oceania, with some countries affected more than the others. The predicted increase in global temperature will affect future heatwaves around the region. Heatwaves have caused increases in morbidity and mortality. They exacerbate existing health issues such as respiratory and cardiovascular conditions and cause heat exhaustion or heatstroke. They also affect workers' productivity. They will also directly and indirectly affect mental health issues (Figure 3.3).

3.2.2 Human response to cold event

A cold wave is a rapid fall in temperature during the winter season. Cold waves are often characterized by the formation of a 'stagnant blanket of thick smoke and fog' that engulfs the low terai belts of Nepal, as well as Bangladesh and the plains of North India.

Cold waves are a recent phenomenon in Nepal. The peak occurrence of a cold wave was experienced in Nepal in 2004, but they have been occurring since 1990. This is suspected to be a result of smog formation from human activities such as the use of fossil fuels and industrial fumes, especially from brick kilns, waste burning, etc. According to the Ministry of Health's Vulnerability and Adaptation Assessment Report in 2015, cold waves affected 262 people in Nepal between 2001 and 2010. Cold wave events were noted in 58 locations in Nepal in 2010 alone (WHO 2015).

Research is lacking in the study of cold waves and their health impacts in Nepal (WHO 2015). Surveillance of cold-related health impacts should be strengthened by the government, which will assist in formulating effective and well-rounded strategies to increase the adaptation capacity of the country's vulnerable populations.

Severe cold waves have become common in Bangladesh over the past two decades (Department of Disaster Management 2014). The recorded cold wave in January 2013 affected more than 20 districts mainly in the north and east, and a few districts in the south, killing 80 people, including children.

In China, cold-related mortality reached 20 times that of heat-related mortality in many areas (Gasparrini and Armstrong 2010). A U-shaped curve between temperature and daily death due to respiratory diseases was found. The proportion of daily deaths due to low temperature was higher than that due to high temperature in Jinan, Shandong province (Li *et al.* 2018). The number of patients with respiratory diseases among the whole population and the elderly (older than 65 years) in Nanjing, the capital city of Jiangsu province, increased significantly by 35% and 53% respectively when cold events occurred (Li *et al.* 2017).

In summary, both heatwaves and cold spells are associated with increases in morbidity and mortality of populations. Heat-related incidences also affect human health through multiple pathways. The main health risks linked to climate change are evident as cardiovascular and respiratory diseases and illnesses. The health effects of global climate change span a continuum from direct to indirect, as discussed in the next section.

3.3 Indirect heat-related health effects

Commonly, most of the population of Asia and Oceania suffer from indirect heat-related health effects, which can be categorized as individual, community, and socio-economic (Figure 3.4).

Individual

- Sleep disorder
- Fatigue/tiredness
- Feverishness
- Decrease in life expectancy
- Increase in infant mortality
- Decrease in athletic endurance

Community

- Domestic disturbances
- Manifestations of hooliganism
- Criminal activities
- Lack of availability and access to clean water

Socio-economy

- Labour productivity loss
- Work inefficiency
- Loss of jobs
- Reduction in agricultural productivity

Figure 3.4 Summary of indirect heat-related health effects.

In the long term, indirect heat-related effects may have greater cumulative impacts on human health. Each EWE caused by climate change affects humans in different ways. If the physical health of an individual is negatively impacted, the decline in mental health will soon follow. These impacts are more gradual and cumulative.

Similarly, there are also large-scale community and social effects, such as conflicts related to subsequent shortages or adjustment after a disaster. The loss of resources can also lead to inter-community violence and aggression. There are threats to emotional well-being through concern and uncertainty about future risks. A community may choose to migrate to find better resources and encroach on another community's territory. Civil unrest may occur when domestic disturbance and criminal activities escalate.

The initial impacts of climate change to economic and social challenges include energy shortages, increasing losses to industry as well as in labour capacity and agriculture productivity. These challenges are interrelated. Economic losses make it difficult to maintain people's livelihoods and can exacerbate social issues such as poverty and hunger.

3.4 Forest fires

Forest fires are occurring more frequently in Asia and Oceania. Climate change, with its record-breaking temperatures and months of severe drought, fuelled a series of wildfires across Australia in 2020. Forest fire has also been a common phenomenon in Southeast Asia over the past few decades.

According to the Bushfire Expert Brief in September 2020 entitled 'After the Bushfires: Addressing the Health Impacts' by the Australian Academy of Health and Medical Science along with Australian Academy of Science, bushfires have adverse effects on people's physical and mental health, with 80% of Australians either directly or indirectly affected (Hughes *et al.* 2020). There were 33 deaths, 3,094 homes lost, more than 17 million

Figure 3.5 Images from the 2019–2020 bushfires in Australia (the Australian Academy of Science).

hectares burnt, and losses of over one billion mammals, birds, and reptiles.

The most recent trauma from the 2019–2020 bushfires (Figure 3.5) is still felt and largely unmeasured in terms of financial losses and health. They must be understood and assessed in terms of a decades-long history of increasing bushfire losses and failure for successive governments to act on climate change. For more information about this issue, refer to the references in Appendix 2.

Climate change is projected to increase the severity of wildfires, especially in the east and north of New Zealand. As well as the risks of burns and injury associated with these blazes, wildfires may be a significant source of health-damaging air pollution, as shown by the Black Summer fires in Australia in 2019-2020. Fine particle pollution from the Australian fires crossed the Tasman Sea and settled in New Zealand but not in sufficient quantities to cause a noticeable increase in respiratory and other illnesses.

According to official sources, there has been an increase in the number of forest and field fires as well as in their coverage of areas in Armenia, attributable both to human and to climate change factors: higher temperature, prolonged dry days, and reduced precipitation. Although heatwaves are more common in the cities of Azerbaijan due to climate change, most natural fires happen in the mountain areas because of the extremely hot weather conditions. This leads to the loss of wildlife and vegetation.

Forest fire haze is not a new phenomenon in Malaysia. It was first recorded in 1982 when regional haze from biomass burning disrupted daily life (Sham 1984; Mohd Shahwahid and Othman 1999). Forest fires play a natural and useful role in the life cycle of a forest and its ecosystem. But fire can also have a devastating long-term effect on ecosystems that are not adapted to such patterns of burning.

Frequent and large-scale fires, mainly caused by increased human activity, affect many forests and peatlands around the world. Tropical rainforests are at particular risk. Fire is used in the management of agricultural activities which sometimes, unmanaged, can consume millions of hectares (Defossé *et al.* 2011). Forest and vegetation fire usually refers to fires in various types of vegetation (savannah and agricultural residue) and peat, whereby these fires are set by human activity or are naturally triggered (Langmann *et al.* 2009).

The term 'biomass burning' is used to describe all types of burning. Biomass burning includes burning of forest grassland, field burning of crop residue, and fuel wood. Burning of vegetation was a common practice to clear vegetation which most likely became uncontrolled enabling large areas of fire (Heil and Goldammer 2001).

A study by Lee *et al*. (2016), found that biomass burning in Sumatra was responsible for 50% of the concentration of $PM_{2.5}$ (particulate matter having a diameter of less than 2.5 micrometres), and for up to 36% of the low visibility in Kuala Lumpur from 2003 to 2014. Significant emissions from biomass burning and forest fires were no doubt the major cause of transboundary haze which impacted both the environment and, most importantly, human health (See *et al.* 2007).

There have been 10.35 million annual average person-days of exposure[11] to wildfires in past 10 years in China. During 2016–2019, 24 of 34 provinces experienced an increase in annual person-days' exposure to wildfire compared with 2001–2005. Among those provinces, the largest annual increase in person-days' exposure was in Heilongjiang and Jilin province, the northeast industrial base in China, followed by Tianjin, the province near Beijing.

Climate change increases the occurrence of wildfires by altering patterns of lightning, fuel moisture, temperature, precipitation, and vegetation. Forest and wildfires not only cause direct thermal injuries and deaths to humans, but can also affect the health of individuals. Forest and wildfires release sulfur dioxide (SO_2), nitrogen oxides (NO_X), ozone (O_3), carbon monoxide (CO), and total suspended particulates in the form of PM_{10} and $PM_{2.5}$ (Aditama 2000). These are hazardous and can damage people's lungs and immune systems, and exacerbate acute and chronic respiratory symptoms. Fires also have effect on cardiovascular morbidity and mortality, and psychological illness (Finlay *et al*. 2012). The effects of forest fires on human health are further elaborated in section 3.8 (Climate change and environmental toxicology: air pollution and other pollutants).

Around 36% of the Indian forest (approximately 657,000 km^2) is prone to fires,

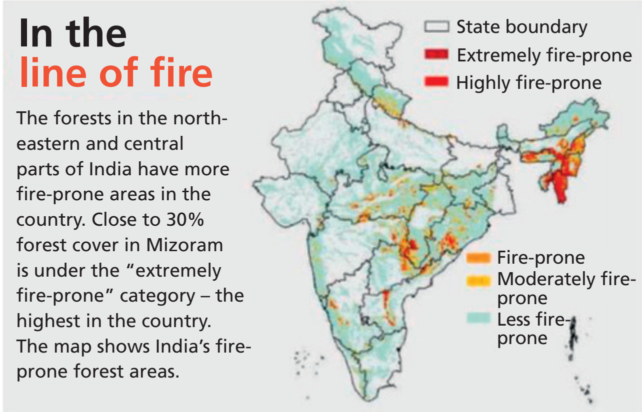

Figure 3.6 Map showing forest areas under different fire-prone classes (Indian Academy of Science; Indian State of Forest Report 2019).

with 10% defined as highly prone, and the northeast of India being the most vulnerable (Figure 3.6). Changing patterns of rainfall and extreme heat events will also influence the susceptibility to forest fires throughout the country in the coming decades. Fires directly affect communities that depend on forests such as tribal populations. In addition to the health effects due to loss of green cover, long-lasting forest fires also cause air pollution, smoke, and smog.

Meteorological factors that decrease the relative humidity and increase the temperature are particularly effective in the formation of forest fires, which are closely related to drought (MGM 2018). As a result, 30,188 forest fires occurred in Turkey between 2005 and 2018, which consumed 106,650 hectares. According to statistics, an average of 2,388 forest fires occurred annually. An average of 6,665 hectares of forest were damaged annually in these fires. While 2,167 forest fires occurred in 2018, 5,644 hectares in total were damaged. It has been reported that 81% of forest fires originate from human intent and omission. Fires caused by natural causes are only 19% (OGM 2018) of the total. These are fires caused by energy transmission lines, mostly owing to lightning and storms (MGM 2018).

[11] Person-time is an estimate of the actual time-at-risk (in years, months, or days) that all participants contributed to a study.

In the Russian Federation Far East, the number of forest fires has increased in recent decades, in parallel with the duration of the fire-hazardous season. From 2000 to 2018, the annual number of cases increased 1.79 times (from 1,960 to 3,526) and the area of burned-out forests rose 8.31 times (from 653 to 5,428 hectares) (Bogatov *et al.* 2021).

The numbers of forest, peat, and bushfires in the region have increased over the past couple of decades. Forest fires in one country can affect those in another. Forest fires cause burns, smoke inhalation, and other injuries. They also release sulfur dioxide, nitrogen oxides, ozone, carbon monoxide, and total suspended particulates in the form of PM_{10} and $PM_{2.5}$, which can have effects on the respiratory, cardiovascular, and immune systems, leading to increases in morbidity and mortality. They also cause psychological illness, with increased mental health issues due to direct fire effects and indirect effects as a cause of the loss of livelihood (Akay 2019).

3.5 Climate and flooding

Every year, thousands of people die in flooding across Asia and Oceania. Flooding is a major challenge, mainly in Southeast Asia. Globally, the rise in flooding incidents and the area affected by monsoon systems is likely to increase in the 21st century. High-density areas of Asia are particularly vulnerable and may face various health challenges such as drowning, injuries, hypothermia, and several infectious diseases, for example cholera and malaria (Patz *et al*. 2014). Nevertheless, there are several regions in Asia more affected by flooding than others.

The unprecedented 'yellow' flood of late December 2014 is a noteworthy example of an EWE in Malaysia. Communicable diseases are obvious health problems that add further complications after a flood. Several studies conducted after the flood of 2014 have provided useful insights on the link between climate change and communicable diseases. Further reading is available in Appendix 3.

Twelve per cent of the land-mass in India (40 million hectares) is prone to flooding, and approximately 5,700 km of the 7,516 km coastline is prone to cyclones and tsunamis. Some of the largest cities in India such as Mumbai, Chennai, Kolkata, and Kochi lie along the coastline, exposed to rising sea levels. The increasing frequency of heavy rain and unsustainable development leading to soil erosion makes the towns and cities extremely vulnerable to flooding.

Excessive melting of glaciers in summers also leads to flash floods. The rate of loss of ice from Himalayan glaciers doubled during 2000–2016 compared with 1975–2000. Water from melting glaciers drains into lakes that eventually feed rivers. However, when overrun with water, lakes with weak moraines[12] can burst, known as glacier lake outburst floods. A simulation study found that around 5,000 lakes in the Himalayan region have unstable moraines and are prone to bursting, leading to flash floods in the lower plains. Several glacier lake outburst floods have been recorded in Nepal, India, Pakistan, and Bhutan.

India's largest river, the Ganga, originates from Lake Manasarovar in the Himalayas. Floods in the Ganga River endanger the lives of over 400 million people who live in the river basin. Floods lead to loss of life, livestock, and livelihoods, as well as safety nets and stability. The indirect adverse effects are loss of drinking water.

China is another country that is vulnerable to floods. Half of the population and two-thirds of the land falls under a heavy threat of floods (Yihui and Jianyun 2009). Floods are also the most common natural disaster in the southern China. In the past 30 years, the frequency and intensity of extreme floods in typical flood risk areas and small/medium-sized river basins in southern China have increased and intensified.

[12] A moraine is a mass of rocks and sediment carried down and deposited by a glacier, typically as ridges at its edges or extremity.

Figure 3.7 The flood-stricken city of Chongqing in southwest China.

Rainstorms in large and super-large cities have also increased. Owing to global warming and rapid urbanization, extreme events such as heavy rainfall and floods are likely to increase in certain parts of China in the future (Jin *et al*. 2018) (Figure 3.7).

Apart from the direct threat to human lives, intense floods also lead to water pollution and food shortages, as well as intensifying the possibility of infectious diseases. They may also cause outbreaks of vibrio and leptospiral bacterial infections (Watts *et al.* 2018).

In addition to the increasing incidence of infectious diseases, floods also have an impact on chronic non-communicable diseases. The impact of floods on human health varies from person to person, depending on the vulnerability of the population (Mallett and Etzel 2017). An analysis of deaths in Hunan Province found that flooding may increase the risk of CVD, coronary artery disease, female mortality, and rural mortality (Li 2015).

The acute effect of flood on chronic diseases has certain lag periods. Acute CVD deaths among women in a flood year (2010) were higher than in non-flood years (2009 and 2011) in Hunan province. The disability-adjusted life year (DALYs) was 115,395 people per year in 2010, which was higher than the figure of 4,108 people per year in 2009 and 26,218 people per year in 2011 (Li 2015).

A survey conducted in Nanning and Huaihua in China also found that the incidence of infectious diarrhoea increased by 4.8% daily during the flood, and that the maximal effect of the flood was observed during the flood month (Liu *et al*. 2016). The lag period varies in different populations.

A series of EWEs in Australia have been the result of ocean warming and heavy rainfalls in recent decades. Heavy rainfall tends to be associated with increased risk of VBDs such as dengue fever and leptospirosis. For example, the flood in Solomon in 2014 led to a nationwide outbreak of diarrhoea, most probably caused by rotavirus. There were more than 6,000 cases and at least 27 deaths.

Rising sea levels in New Zealand have caused a steep increase in the frequency of events that are rarely experienced, and therefore qualify as EWEs. For instance, flooding only happens once in a hundred years, on average. These extreme events are important for health and other sectors because they can be used as a benchmark for designing and planning operations in infrastructure, land use regulations, and flood preparations.

Flooding in Dunedin in 2015 and Edgecumbe in 2017 led to the dispersal of toxic chemicals, damp houses, mental health issues, and disruptions to essential services. The health-care centre in Edgecumbe, was closed for 10 months after the flood.

The increase in coastal flooding that is projected for the remainder of this century will multiply such hazards. Some Māori communities will be particularly vulnerable to increased flood risks due to climate change and the location of valued infrastructure and sacred sites on exposed, erosion-prone coastal lands.

It is important to bear in mind that most of the literature cited on CC&H in New Zealand actually draws on research about the relation between weather and health. There are few studies of climate ‘average weather’, and health, given this requires observations extending over decades or more. Studies of heatwaves, for instance, commonly relate daily temperatures to deaths and illness occurring shortly afterwards. It is inferred that climate change will lead to more frequent heat events, and hence cause health losses, but it is not possible to observe these effects directly.

More intense precipitation is projected for many places; the variability of rainfall may also increase. In New Zealand, for instance, annual rainfall is projected to increase substantially in the west and south of the country, and to decline in eastern regions.

Heavy precipitation, snowmelt, river inundations, as well as damage to hydro-technical installations are the main reasons for floods in Armenia. The year 2007 was notable in terms of excessive floods (86 cases were recorded). This phenomenon was significantly observed in Vayots Dzor and Gegharkunik marzes[13] (22% and 15%, respectively).

During 2012–2018, a considerable decrease in the number of cases of floods was observed. On average, the annual number of cases was seven, in contrast to over 30 registered annually during 2005–2011. The highest number of floods was recorded during months in spring.

Most mudflow-related phenomena in Armenia are caused by the mountainous terrain, heavy rainfalls, and rarely by snowmelt. The highest number of cases of mudflows, around 80%, was registered in May and June. As with the case of floods, 2007 was also notable for excessive mudflows: the number of registered cases was 38.

The Far East is one of the regions of the Russian Federation most affected by floods. Its rivers are characterized by an uneven water regime, one of the phases of which is floods. The highest water content of most rivers is observed during floods in the summer–autumn period, when up to 80% of their annual run-off passes. The areas most affected by flood hazards in the Far East include Yakutia, Primorsky, and Khabarovsk territories, and the Amur and Sakhalin regions.

[13] Marz (plural: marzes) is the name for a first-level administrative entity in Armenia. In English, it is usually translated as province or region.

In most of the region, the frequency of floods is once every 4–6 years. The exception is the territory of the Kamchatka region, where floods are observed much less frequently—once every 20 years. In the past few years, the frequency of floods has been increasing. For example, on the River Razdolnaya in alignment with the River Novogeorgievka in Primorsky Krai, excess water levels classed as a dangerous phenomenon were observed for 4 years in a row, from 2015 to 2018. During severe floods in the south of Primorsky Krai, serious economic damage caused a state of emergency to be declared at the federal level.

The most frequently experienced natural disasters in Turkey are storms, floods, droughts, and forest fires. These disasters can often cause injury to individuals and sometimes even death. The year 2019 had the largest number of extreme events: 935. There has been an upward trend in extreme events, especially in the past two decades.

As one of the EWEs in the most common types of natural disaster, flooding has led to significant loss of life and property in Turkey. Higher incidences and severity of floods have started to have devastating results, especially in the past 10 years (Akay 2019).

In addition, excessive rainfall, stagnant water, or overflow of rivers has caused escalations in infectious diseases due to the increasing number of flies. Turkey is expected to be the most effected country from extreme weather conditions among Eastern Europe, the Balkans, Eurasia, and the Turkic states up to the end of the 21st century (Baettig *et al.* 2007).

In conclusion, climate change is expected to lead to an increase in extreme rainfall, especially in places where mean rainfall is also expected to increase such as in Asia and Oceania. Kulp and Strauss (2019) find that the new elevation data suggest significant increases in global vulnerability to sea-level rise and coastal flooding. Therefore, changes in seasonal and annual rainfall will be important factors for understanding future flooding.

3.6 Infectious disease threats

Changes in temperature, precipitation, and humidity have a very profound effect on the life cycle and growth of infectious agents and vectors. Hence, the transmission of water and food-borne diseases are at a peak after raining and flooding season. Flood can influence the transport and dissemination of infectious agents, while temperature affects their growth and survival. In the other hand, climatic variables (air/sea temperature, rainfall, and humidity) affect transmission of VBDs, mostly by altering the behaviour and adaptation capacity of its vectors.

3.6.1 Water- and food-borne diseases

Water-borne diseases are caused by recreational or drinking water contaminated by disease-causing microbes or pathogens. Many water-borne pathogens can also be acquired by consuming contaminated food or beverages, from contact with animals or their environment, or through person-to-person spread. The most common water-borne diseases are cholera, diarrhoea, hepatitis A, typhoid, malaria, and viral gastroenteritis.

In South Asia, Pakistan has the highest incidence of typhoid fever (451.7 per 100,000/year), primarily caused by infections of *Salmonella enterica* serovars Typhi (*S.* Typhi) and Paratyphi (*S*. Paratyphi) (Ochial *et al.* 2008). Hepatitis accounts for nearly 50–60% of acute viral hepatitis cases in the country's paediatric population. Polluted water is often the source of pathogenic organisms in many food-borne epidemics. The emergence of extensively drug-resistant strains of these organisms poses a serious threat to the health of Pakistani people.

In Nepal, outbreaks of water-borne diseases, including life-threatening ones such as cholera, have been frequent in recent years (Department of Health Services 2016). Several studies have examined the effects of temperature rises and varying rainfall patterns as a result of climate change, where water-borne diseases such as diarrhoea and cholera commonly inflict children, and often result in fatalities due to poor management and adaptation capability. Most of these studies have found that both temperature and rainfall factors are associated with outbreaks of water-borne diseases (Dhimal *et al.* 2018).

A report examining the links between temperature and diarrhoea data from July 2002 to June 2014 stated that the incidence of diarrhoeal diseases increased by 4.39% for every 1 °C increase in ambient temperature. Additionally, it found that an increase of 1 cm in rainfall was linked with a 0.48% increase in diarrhoeal cases (Dhimal *et al.* 2018). It noted that mountain areas showed more variability in temperature and precipitation, making them more susceptible to increases in the incidence of water-borne diseases.

Studies have shown that epidemics of dengue in the South Pacific positively correlate with La Niña[14] events. Changing weather patterns and human behaviour can also lead to increased instances of zoonotic diseases such as severe acute respiratory syndrome (SARS), Middle East respiratory syndrome, and severe acute respiratory syndrome coronavirus 2 (SARS-CoV2). An analysis of emerging infectious diseases between 1940 and 2004 showed a steady increase over those decades. Sixty per cent of emerging infectious diseases are zoonotic, mostly originating from wildlife.

The Ministry of Health and Family Welfare in India estimates that water-related diseases affect 40 million people annually (Bush *et al.* 2011). Only 25% of the Indian population has access to piped water. Lack of safe drinking water near homes forces people either to spend time and energy bringing water from far-off places or to use unsafe water. This is generally considered to be a problem with rural life but rising population densities and lack of housing and sanitation make safe drinking water in cities even more of a problem. The study estimates that 21 cities in India will deplete their groundwater by 2020. A drought in 2019 caused the water supply to dry up in Chennai and led to a crisis in the city.

Unsafe water results from many different situations. Frequent floods lead to water contamination with human and animal waste, causing an increase in diarrhoeal diseases. Outbreaks of diarrhoea from cholera, rotavirus, and leptospirosis have been documented following floods in India and Bangladesh. Flooding due to cyclones also causes contamination of water in coastal areas. Loss of sanitation and hygiene following displacement of people in such events is usually a hotbed for water-borne diseases. Diarrhoeal diseases, due to contaminated water and food, are the major cause of mortality in children in South Asia. Data now show that warmer climates, heavy rainfall, flooding, and drought cause an increase in water-borne diarrhoeal diseases.

Food-borne illnesses can be caused either by infectious agents or by chemical contamination. Children younger than 5 years carry 40% of the food-borne disease burden across the world. In Bangladesh, watery diarrhoea among the displaced population due to floods is the most common cause of death for children under 5 (Noé *et al.* 2018). Vulnerability to diarrhoeal diseases is high among the populations of floodplains and river delta areas.

According to the analysis of pathogens collected through the Korea Centre for Disease Control and Prevention's water- and food-borne infectious disease pathogens monitoring project from 2016 to 2018, *Salmonella* and pathogenic *Escherichia coli* had a high separation rate from June to October, and from June to August in the case of *Campylobacter* species. These results can be attributed to diseases caused by water- and food-borne infection-causing bacteria during the hot and humid summer months (Korea

[14] La Niña is simply a 'cold event', representing periods of below-average sea surface temperature across the east–central Equatorial Pacific. La Niña means 'The Little Girl' in Spanish and is sometimes called El Viejo, the opposite of El Niño.

Centre for Disease Control and Prevention 2019a).

From 2006 to 2015, food poisoning from norovirus occurred mainly in winter. Among the climatic factors, average temperature, highest and lowest precipitation, precipitation days, and humidity showed significant negative correlations with the number of monthly norovirus food poisoning cases ($p<0.05$), with the lowest temperature ($r=-0.398$), and the average temperature ($r=-0.396$). However, the sum of the rate of norovirus food poisoning in spring and autumn was similar to that in winter (Kim and Kim 2019).

In recent years, warming has helped to spread infections by *Vibrio vulnificus*, a Gram-negative proteobacterium found in highly enclosed brackish water zones; many cases of these infections have been reported in the Kyushu region of Japan. This bacterium causes diarrhoea, abdominal pain, and skin disorders. A positive correlation was found between the amounts of the bacterium and sea surface temperatures and salinity, with detected quantities increasing when saltwater surface temperatures were 20 °C and above. The northern limit of the 20 °C zone has tended to shift further northwards in recent years (Yamasaki *et al*. 2009; MEXT *et al.* 2013). Similarly, reports from throughout Japan have indicated that an increase of sea surface temperature also caused increases in the number of *Vibrio parahaemolyticus*, a Gram-negative proteobacterium that is parasitic on fish and shellfish during the summer season (Goto *et al.* 2011; Arizuka *et al*. 2013; Kanatani *et al.* 2014)

Water-borne infections are a particular challenge in New Zealand, where rates of gastroenteritis are already relatively high compared with other high-income countries. In part this may be traced to the prevalence of untreated drinking water supplies, large numbers of livestock, and high rainfall.

Water-borne infection rates are projected to increase due to climate change (Project Team for S-8 Climate Change Impact and Adaptation Research 2014). A study using the Special Report on Emissions Scenarios (SRES)[15] predicted that diarrhoea due to climate change would increase in Africa and Asia, except in high-income regions, whereas rates of diarrhoea were expected to decrease in Japan (Tang and Itsumo 2011; WHO 2014). This is due to pollution of the existing water supply from industrial activities and flooding, and a reduction in sources of clean and potable water supplies, for example in India. A proper management system for clean and potable water sources is important in reducing the risk of water-borne diseases in the future.

3.6.2 Vector-borne diseases

VBDs result from an infection transmitted to human and other animals by blood-feeding arthropods such as mosquitoes, ticks, and fleas. Examples of VBDs include Crimean-Congo haemorrhagic fever, West Nile fever, tick-borne encephalitis, Japanese encephalitis, dengue, malaria, Ross River fever, chikungunya, visceral leishmaniasis[16], and tularaemia (Table 3.2). Outbreaks of serious VBDs have been detected in Nepal, Armenia, Japan, and Bangladesh.

Malaria is a great health burden in India and Bangladesh. It is known that malaria increases five times in the hot–humid year after an El Niño event (Bouma and Van Der Kaay 1996). Increasing rainfall in hot and dry regions encourages mosquito breeding. Similarly, cooler northern regions are estimated to have longer durations of mosquito infestations with increasing average global temperature.

Another epidemic spread by mosquitoes, dengue, has wreaked havoc since the 1960s.

[15] Special Report on Emissions Scenarios (SRES). This report was accepted by the Working Group III (WGIII) plenary session in March 2000. The long-term nature and uncertainty of climate change and its driving forces require scenarios that extend to the end of the 21st century. SRES describes the new scenarios and how they were developed.

[16] Also known as kala-azar.

The 1996 epidemic affected 16,517 people and killed 545 in Delhi.

Dengue was not prevalent in Bangladesh before 2000, but cases started to increase at an alarming rate, with high morbidity and mortality for the next few years. After the initial devastation, it finally came under control. However, it appeared again in 2019, when the country experienced the maximum number of mortalities from it in its history (Figure 3.8).

Most of the cases of dengue and chikungunya are observed in Dhaka, Chittagong, and Khulna, with the highest incidence rate being in Dhaka. Many of the urban environmental issues such as lack of proper waste management, open drains with dirty water, and drainage congestion are the reasons for such high prevalences of these mosquito-based diseases in the big cities. Climate change will further exacerbate this.

Table 3.2 Examples of vector-borne diseases, their vectors, and infectious agents

Mosquitoes/vectors	Diseases
Aedes albopictus	Dengue fever, chikungunya, yellow fever, Zika virus
Aedes aegypti	Malaria, yellow fever, dengue fever, chikungunya, Zika virus
Ticks	Japanese spotted fever, Lyme disease
Culex vishnui, *Culex tritaeniorhynchus*	Japanese encephalitis, West Nile fever
Phlebotomus argentipes sandflies	Leishmaniasis
Fleas	Plague, tularaemia

Nepal is endemic for at least six major VBDs that are transmitted by the bites of infected mosquitoes and sandflies (Dhimal and Karki 2014; Dhimal *et al*. 2015; Department of Health Services 2016). These VBDs continue to spread to regions previously thought non-endemic to them, despite measures taken to control the spread in the past decade under the Millennium Development Goals and Roll Back Malaria programmes (Nepal Planning Commission 2011).

The evidence gathered on climate change and VBDs shows an increasing risk of incidence, eliciting an urgent need to strengthen Nepal’s social, economic, and health systems, to increase the capacity to efficiently manage spread and prevent future outbreaks (Dhimal *et al*. 2017).

Pakistan has had several dengue outbreaks in the past 10 years. In 2011, more than

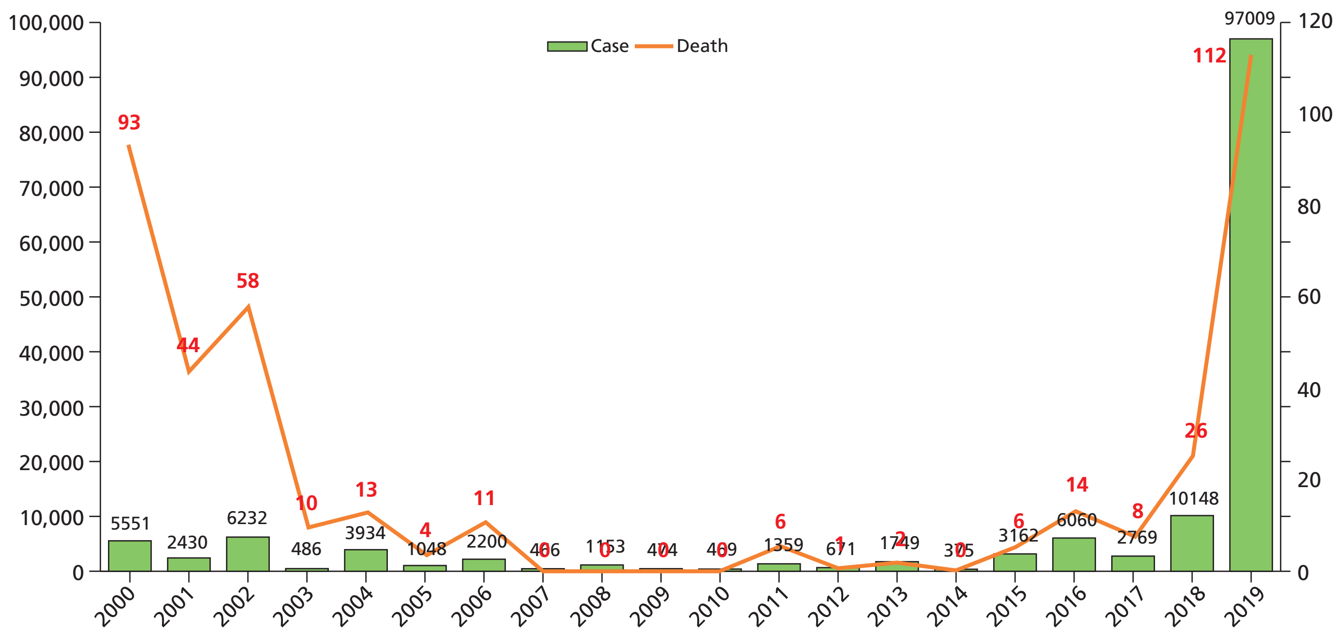

Figure 3.8 Annual dengue cases and deaths in Bangladesh (2000–2019). Data source: control room, DGHS.

22,000 cases were reported from Lahore with more than 350 deaths. In 2019, more than 44,000 people were affected by dengue fever followed by scores of deaths. Besides dengue, Zika virus, chikungunya, and malaria are among the major VBDs in Pakistan, with numerous cases reported every year.

Malaria and dengue also becoming a health issue in Malaysia and Indonesia. Frequent flooding due to EWEs related to climate change in the past decade has increased the risk of these VBDs. It is believed that still waters persisting after floods are breeding grounds for *Aedes* mosquitoes. Climatic factors including temperature, rainfall, and humidity have been associated with floods. The lag period between rainfall or temperature change and outbreaks of dengue ranges from 7 to 51 days, providing a window or lead time for mitigation control (Hashim and Hashim 2016).

From 1994 to 2005, outbreaks of malaria (exclusively cases of *Plasmodium vivax*) were registered in Armenia. In 2006, thanks to efficiently coordinated and complex measures, local transmission of the disease was interrupted. In 2011, Armenia was certified by the WHO as a malaria-free territory. Although afterwards some imported cases of malaria were registered in the country, these were quickly diagnosed, quarantined, and treated. Nowadays, only some unique imported cases of the disease are revealed occasionally. Currently, the main objective of malaria surveillance is the prevention of reintroduction of the disease in the country.

During the Soviet period, numerous cases of visceral and cutaneous leishmaniasis were registered in Armenia. Since 1999, new cases of visceral leishmaniasis have been periodically detected, the consequence of survival of the infection in animals (such as canines) as natural reservoir hosts, and the transmission from animals to humans through infection from ticks that breed in dumps with organic waste (Table 3.3).

Table 3.3 Leishmaniasis cases in Armenia according to the Ministry of Health

Year	2010–2014	2015	2016	2017
Number of cases	7–9	18	10	17

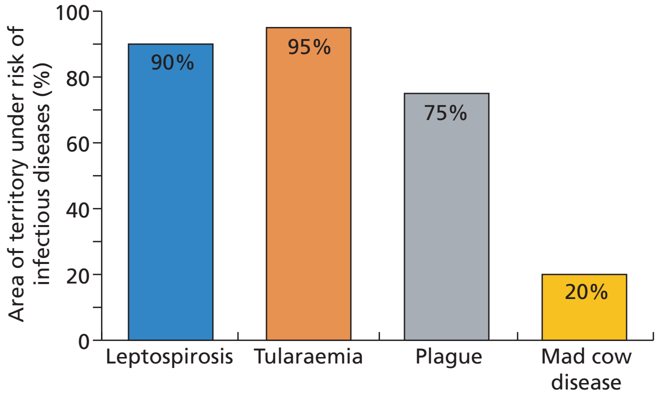

Figure 3.9 Infectious diseases in Armenia.

In 2015, surveys were conducted to assess the real scope of the incidence of leishmaniasis in various marzes and the risk factors contributing to the spread of the disease. The surveys were based on systematically sampling the populations in the Syunik, Tavush, Lori, Ararat, and Armavir marzes of Armenia, and the Kanaker-Zeytun, Nor Nork, Avan, Arabkir, Erebuni, Nubarashen, and Shengavit administrative districts of the city of Yerevan.

During recent years, sporadic cases and local outbreaks of anthrax have been registered in Armenia resulting from cases of the disease spreading among animals. In the past decade, the highest numbers of cases of anthrax were registered in 2012 and 2013, with 11 and 19 cases respectively. Thus, from time to time, cases of anthrax are detected. Given that anthrax spores can survive in the environment for 100–150 years, it can be forecast that cases of this disease will continue to occur in the future.

A considerable part of Armenia is a natural focus[17] for several dangerous infectious diseases, as shown in Figure 3.9. Tularaemia

[17] Focus (plural: foci), the centre of interest or activity.

is occasionally also accompanied by outbreaks of sporadic cases of morbidity among humans. From 1996 to 2017, an increasing trend in epizootics was observed while the number of cases among humans decreased. Infected mammals and ticks may function as transmission reservoirs of *Francisella tularensis* to humans.

In Japan, the geographical distribution of vector organisms has widened, with longer periods during which vectors can remain active. One great concern is the invasion of vectors from the other countries. For example, dengue fever from an outside source was reported in a Tokyo park in the summer of 2014, and domestic dengue fever was reported in the Kansai region in 2019 (MHLW 2019). These occurrences suggest the risk of widespread infection in Japan because of pathogens originally brought in from overseas.

Since 1950, the habitat of *Aedes albopictus* has gradually moved north to the northeastern regions, with confirmed sightings in Aomori Prefecture in 2016 (Sato *et al*. 2012; Nihei *et al*. 2014; Takasaki 2011). Another example is that mosquitoes have been found on Ishigaki Island since 1990 and reached the area's main island Okinawa in 2002 (Toma *et al*. 2015). Increasing trends have been confirmed for dengue, chikungunya, and other infections imported into Japan (Takasaki 2011; Morita 2016).

The growing numbers of foreign visitors are expected to contribute to a higher number of imported pathogens. The population density of *A. albopictus* is high throughout Japan, especially in Tokyo (Kobayashi *et al*. 2014). This raises serious concerns about the risk of an imported infectious disease stimulating an infection chain in Japan. Ticks can also be vectors of infections such as Japanese spotted fever, which is showing an increasing trend nationwide. Although the numbers of patients with tsutsugamushi disease[18] (scrub typhus) have been declining in recent years, they are still high (Yoshizumi *et al*. 2017). Because the winter season begins later owing to temperature increases, the epidemic period for Japanese spotted fever has shifted to the end of the year (Yoshikura 2017), and a positive correlation has been reported between the number of cases of tsutsugamushi disease and the previous fiscal year's average temperature, rainfall, snowfall, and snow accumulation (Seto *et al*. 2017).

In January 2013, there was an outbreak of severe febrile thrombocytopenia syndrome, another tick-borne infection. Although the relationship between this syndrome and climate change is still not clear, the number of reported patients with it has been increasing annually, with 2019 marking a record high of over 100 cases.

A projection of *A. albopictus* distribution using several scenarios showed that, although this mosquito species was currently distributed in about 40% of the Japanese territory, the RCP 8.5 scenario indicated that its distribution range would be extended to around 75–96% by the end of the 21st century (Project Team for S-8 Climate Change Impact and Adaptation Research 2014).

A Model for Interdisciplinary Research on Climate (MIROC) K1 scenario projection indicated that, by the end of 21st century, the average daily temperature would reach 11 °C and above. This is the temperature required for *A. albopictus* development, suggesting that the geographical distribution of this mosquito may broaden to include the southern portion of Hokkaido, currently an area where its invasion or establishment has not been found (Kobayashi 2015). *A. albopictus* begins feeding in early spring. A projection indicated that a rise in ambient temperature would bring forward the start of feeding (Komagata *et al*. 2017).

[18] A rodent-borne infectious disease caused by the Gram-negative proteobacterium Orientia tsutsugamushi, characteristically with fever, headache, a raised rash, swollen glands, and a dark, crusted ulcer at the site of the bite. The disease occurs in the area bounded by Japan, India, and Australia.

Culex vishnui was projected to spread to Kagoshima Pre-fecture and northwards if ambient temperatures continued to rise (Toma *et al*. 2015). For *Aedes aegypti*, a future temperature increase of even 3 °C would mean that winter temperatures in most regions of Japan (other than in Japan's southwest islands) would still not exceed 10 °C, the temperature required for this mosquito species to hibernate (Komagata 2017). Nonetheless, the possibility of *A. aegypti* hibernating in indoor environments maintained at a certain temperature cannot be ruled out. Although climate change is also expected to affect the spread of infectious diseases vectored by arthropods other than mosquitos, no studies have specifically assessed this.

Higher temperatures and changing rainfall patterns increase both the reproduction and biting rate of vectors. For example, the vectorial capacity for *A. aegypti* and *A. albopictus*, two types of mosquito that transmit dengue, is found to have increased by 37% and 14% respectively during 2014–2018 in China compared with the average value for 1961–1965. The increasing vectorial capacity has therefore led to a considerable and continuous growth in both the incidence rate and DALYs for dengue fever in China (Cai *et al*. 2021).

In 2017, the all-age incidence rate and DALYs of dengue fever increased by 5.7 and 4.7 times compared with that of 1990, reaching 183.8 and 1.8 per 100,000 respectively. The largest increase in incidence rate and DALYs was seen in Taiwan, Macau, and Guangxi province (Cai *et al*. 2021).

Climate change may also result in the introduction of infectious diseases into previously unaffected geographical areas. Owing to increasing climate suitability, China has witnessed an obvious northward shift of dengue cases in recent years.

China experienced an unprecedented multi-site indigenous outbreak of dengue in 13 provincial-level administrative divisions, which is significantly higher than the average level (3.67 divisions per year) from 2013 to 2018 (Cai *et al*. 2021).

At present, mosquito species that most commonly transmit malaria and dengue fever are not found in New Zealand. However, vectors are commonly intercepted at the border, owing to the high volumes of trade between New Zealand, Australia, and the Pacific Island states, and infected travellers bring diseases such as dengue and Ross River fever into the country. The risk of dengue remains low under most climate projections for the remainder of this century but rising temperatures and changing rainfall patterns in New Zealand will generally make it easier for mosquitoes to become established, and, in these circumstances, it is possible that local transmission will occur.

As a summary, changing climate is aggravating the threats of infectious disease. We do know that infections that are transmitted through water, through food, or by vectors such as mosquitoes and ticks are highly sensitive to weather and climate conditions. The warmer, wetter, and more variable conditions brought by changing climate are therefore making it easier to transmit diseases such as malaria, dengue, chikungunya, yellow fever, Zika, West Nile virus, and Lyme disease in many parts of the world, especially in Asia and Oceania.

3.7 Food and nutrition security and agriculture

Progress in reducing undernourishment and hunger in Asia has slowed tremendously. The Food and Agriculture Organization (FAO)'s estimates show that the number of hungry people is increasing due to the effects of climate change in recent years. The situation is making it difficult to achieve the Zero Hunger target of SDG 2. It is similarly challenging in nutrition and food security as in health areas.

3.7.1 Food and nutrition security

A higher risk of food insecurity and malnourishment exists for Asian countries. A significant proportion of undernourished people are found to live in developing countries, wherein two-thirds live in Bangladesh, China, India, Indonesia, and Pakistan, and over 40% of them live in China and India (FAO 2010b). Out of the total of 812 million undernourished people worldwide, 276 million lived in southern Asia in 2017, which is the highest number of undernourished people in Asia (FAO 2019). The proportion of undernourishment in South Asia is higher than the Asian and world averages.

Malnutrition is a major health threat in India, Pakistan, and Nepal. A significant population of South Asia faces the issues of undernutrition and anaemia. A high proportion of undernutrition could lead to stunting, wasting, and underweight. The increase in poverty worsens the situation, affecting the health of the masses and making them vulnerable to common diseases.

Apart from nutrition, the underweight and overweight of adults are also linked with lifestyle, particularly in urban areas. The weight issues associated with other health problems, such as hypertension and diabetes, may further escalate parallel to atmospheric and socio-economic consequences resulting from climate change.

Most populations in South Asia derive their nutrients from plants. Elevated carbon dioxide (CO_2) levels would directly impact nutrient concentrations in food. Studies have shown that many food crops have 3–17% lower concentrations of iron, zinc, and protein when grown in atmospheric CO_2 levels higher than 550 parts per million. Estimates show that an

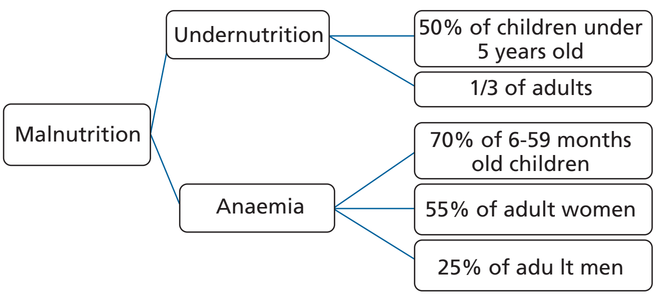

Figure 3.10 Projection of malnutrition in India (2015–2016).

additional 122 million people will be protein deficient, 175 million zinc deficient, and there will be a loss of more than 4% dietary iron as a result of climate change.

Several attempts have been made to quantify the effects of climate change on food security. Global assessments of the effects of climate change on food production have been downscaled to the national level to understand the effects of rising temperatures and changing rainfall patterns on food supply, production, affordability, and damage on the infrastructures of the supply chain as well as the consequent health effects (Gregory *et al*. 2005).

In one modelling study on global and regional health effects of future food production under climate change, it was projected that an additional 140 deaths in New Zealand would occur in 2050 as a result of climate stresses on fruit and vegetable production (Springmann *et al*. 2016). However, New Zealand is a major food exporter and produces a great variety of goods, even under the most adverse climate scenarios. It is anticipated there will be a sufficient supply for the national population. Perturbations in global food markets may cause economic hardship to some sectors but also provide opportunities for agriculture in New Zealand.

Australia is one of the most food secure of all countries but climate change with erratic weather and drought and a rising urban population is threatening all of this. In 2019, the Australian Farm Institute reported that EWEs threaten food supply and prices, and that if Australia were unable to mitigate and adapt practices to the negative impacts of climate change, the agricultural sector would fail its security maintenance. In 2019, a hunger report recounted that 5 million Australians were 'food insecure' (FoodBank Hunger Report 2019; https://www.foodbank.org.au/wp-content/uploads/2019/10/Foodbank-Hunger-Report-2019.pdf).

Many food-borne infections are sensitive to temperature. In Australia, it has been observed the risk of falling ill due to food contamination by salmonella, for instance, is approximately twice as high in heatwave conditions as at other times. In a 40-year period (1965–2006), a 1 °C increase in monthly average ambient temperature in New Zealand was associated with a 15% increase in salmonellosis notifications within the same month. Higher temperatures may increase the number of microorganisms present in foods pre-harvest, and may also increase the risk of contamination during transport, storage, and preparation.

Similar risks apply to marine foods. Rising sea surface temperature is directly related to microorganisms and biotoxins level in seafood. Studies in New Zealand show that heavy rains have caused contamination of shellfish beds with pathogenic organisms. Changing environmental conditions may also lead to increased levels of heavy metals in the food supply.

A higher temperature increases the rate of methyl mercury formation by microorganisms in marine waters and sediments, resulting in larger amounts of mercury accumulating in the food chain. This is critical in New Zealand where fish are the major source of mercury in the national diet.

Studies show that the impacts of climate change will be experienced by nations to varying degrees. Hotter regions are more likely to be affected by food insecurity issues than colder ones. Additionally, low-income countries with limited resources such as Nepal, India, and Pakistan are more vulnerable (Pant 2012). Food insecurity adds a burden to the issue of childhood and adult malnutrition; hence, it is vital to explore this, especially where agriculture is supported by subsistence farming.

3.7.2 Agriculture

Figure 3.11 shows some of the effects of global warming on agriculture. Although the maximum allocation of croplands to coarse grains can improve the stability of the grain supply in drought conditions, the overall yield would reduce. Thus, improving the yield of coarse grains without losing their resilience will be important in improving food security in the future. In recent years, the volume of damage caused by the effects of climate change to agriculture in Armenia is estimated to be around EUR2.5–5 billion annually. Hailstorms are the main cause of the damage. In 2014–2017, the total damage caused by hailstorms was estimated to be about EUR10.5 billion. Table 3.4 shows the effects of climate change, internal factors, and the impacts on agriculture in Armenia.

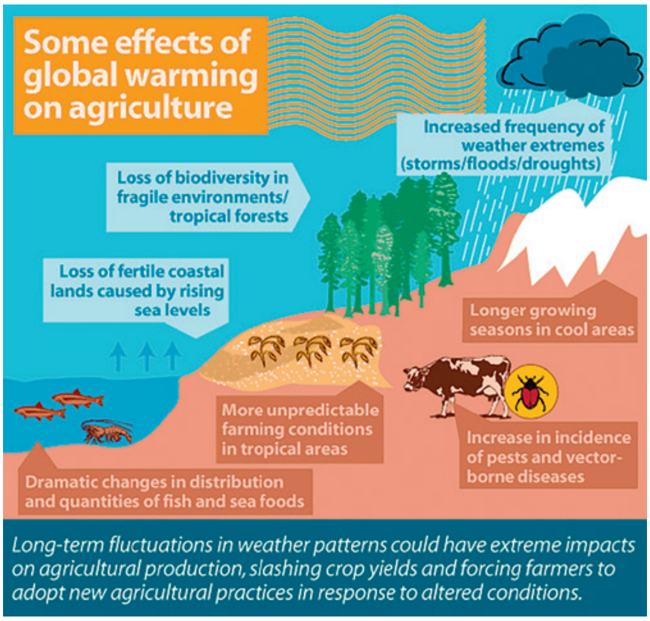

Figure 3.11 Some effects of global warming on agriculture.

The same situation has happened worldwide. The statistics from Turkey (Table 3.5) confirm this impact further.

Meanwhile, 48% (or EUR75.13 billion) of Armenia's gross agricultural output derives from livestock breeding (2017). The main livestock is cattle, which provides over 75% of the gross agricultural product, followed by pig, sheep, and poultry (in almost equal percentages).

[19] Among others: fragmented landscape, slope's degree of inclination, altitude, and geographical position.

Table 3.4 The effects of climate change, internal factors, and the impacts on agriculture in Armenia

Effects of climate change	Droughts, hailstorms, spring frost, inundations, precipitation, water and wind erosion, hot dry winds, lack of humidity, landslides, heavy rainfall, floods, natural salinization and alkalization, waterlogging and eutrophication, geomorphological peculiarities[19]
Internal factors	• Highly expressed vertical zoning • Scarcity of land resources (0.16 hectares of arable land per head) • Fragmentation of the mountainous terrain • Dry and continental climate • Significant losses in the irrigation system • Unsatisfactory state and operation of risks prevention systems • Inefficient exploitation of land resources • Improper farming practices
Impacts on agriculture	• Intensification of land degradation and desertification processes • Decline and loss of agricultural crops yields • Reduced nutritional value of agriculture products • Increase in the demand for irrigation water • Decrease in the volume of irrigation water reserves • Increase in frequency, intensity, and duration of climate hazards and expansion of the spatial distribution • Serious problem for livestock (field fodder production) • Composition and spread of diseases of agricultural animals (natural focal and communicable infections)

Table 3.5 The effect of climate change on the yield of agricultural products in seven regions in Turkey (Dellal *et al.* 2011)

	Wheat (%)	Barley (%)	Corn (%)	Cotton (%)	Sunflower (%)
Black Sea	–6.0	7.0	–7.4		5.0
Marmara	–10.3	–8.5	7.9	–5.0	–5.9
Aegean	–7.2	–7.2	–11.0	–3.6	–6.6
Mediterranean Sea	–6.5	–6.0	–10.9	–2.8	–6.8
Central Anatolia	–7.4	–8.2	–12.5		–7.3
Eastern Anatolia	–8.3	–8.5	–12.1		–7.9
Southeastern Anatolia	–7.2	–7.5	–9.2	–4.0	–6.3
Turkey	–7.6	–7.6	–10.1	–3.8	–6.5

Studies show that Armenia is still vulnerable to diseases, particularly blood-borne parasites. The most frequent incident in agriculture is blackleg[20]. In June–July of 2017 and 2018, unprecedentedly high temperatures from 41 °C to 42 °C were recorded in the country. In those months, the incidence of cattle falling sick with blackleg was 20–25% higher than in the years with lower summer temperatures.

Similarly, some areas previously considered non-vulnerable have now become vulnerable to blood-borne parasitic diseases, blackleg, and several other diseases. New vulnerable regions may emerge in areas of Syunik, Shirak, Gegharkunik, and Aragatsotn provinces that are 1600–2000 metres above sea level.

Compared with other sectors, agriculture is the most dependent on climatic conditions. Agricultural production is sensitive to weather and therefore directly affected by climate change. Currently, non-seasonal weather conditions are observed in Azerbaijan. The winter in 2020 was the most severe and, during some days, the lowlands registered a 15–20% decrease in the average temperature. The impacts of climate change on agriculture

[20] Blackleg is a serious disease of canola across all growing areas. Field scouting and accurate identification of the symptoms are required to diagnose this disease.

Table 3.6 Summary of the impacts on agriculture and livestock in Azerbaijan

Agriculture	Livestock
• Decrease in rainfall in remote areas causing lower productivity • Increasing spring droughts • Decrease in irrigation due to water scarcity in irrigation systems causing lower productivity (cotton, grain) • Lack of irrigation water despite increasing demand for water from crop products • Changing duration of seasonal vegetation planting causing disturbance in delivery of agriculture products	• Decreased productivity in natural pastures causing increased risk of erosion • Increase in infectious diseases • Increase in desertification causing reduction in natural pastures and hayfields • Decrease in biodiversity and vegetation in natural pastures

and livestock in Azerbaijan are summarised in Table 3.6.

Predicted scenarios of agricultural development in a changing climate are necessary to provide strategies and decision-making tools to improve agriculture and food security, and, at the same time, to reduce the negative impact of agriculture on the environment.

The geographical location of the Russian Federation Far East, with its typical soil and climatic conditions, makes it possible to grow a wide range of agricultural crops: soybeans, spring crops, fodder crops, corn, potato, rice, as well as vegetables and fruit although at quite a distance from the area's northern border. Dairy and cattle breeding, and pig and poultry farming, are also quite promising in northern Asia, equal to horse breeding and reindeer husbandry in the northern regions. In addition, there is development of mariculture[21] in the coastal areas of the south.

The problem of food self-sufficiency has been characteristic of the Russian Federation Far East for one and a half centuries of its existence. During the period of industrial development from 1960 to 1985, the area of agricultural land in the region approached 3 million hectares. During the crisis of 1990–2005, a significant part of the cultivated land was withdrawn from circulation and only in 2005 began its return to the agricultural sector. To date, the main agricultural arable land in Amur region, Khabarovsk territory, and Primorsky territory consists of 2.5 million hectares (2% of the arable land of the Russian Federation and 10% of northeast China). This resource, at a regional scale, is vital for the Russian Federation and northern Asia (Bogatov *et al.* 2021).

Agriculture has not yet accomplished food self-sufficiency in the region. However, the natural and technological conditions of the south could make it happen in the future by increasing the area of arable land, as follows:

(1) up to 3 million hectares, through the reclamation of land that has been abandoned;
(2) up to 4–4.5 million hectares, through new land melioration and development.

Realistically, increasing agriculture, which is based on 'new' development, will be largely determined by trends in climate change. Strategic adaptation planning, along with other factors, is necessary to strengthen food security in order to accommodate climate change:

(1) In the Russian Federation Far East, the agro-ecological significance of climatic changes will be maximal in the forested area (Prikhankaiskaya lowland, south of the Zeya-Bureya plain), where in spring and early summer aridization is likely to increase.
(2) In Northeast Asia, the agro-ecological significance of climate change will be maximal in the western part of Heilongjiang and Jilin provinces in the

[21] Mariculture is a special branch of aquaculture involving the cultivation of marine organisms for food and other products in the open ocean, an enclosed section of the ocean, or in tanks, ponds, or raceways which are filled with seawater.

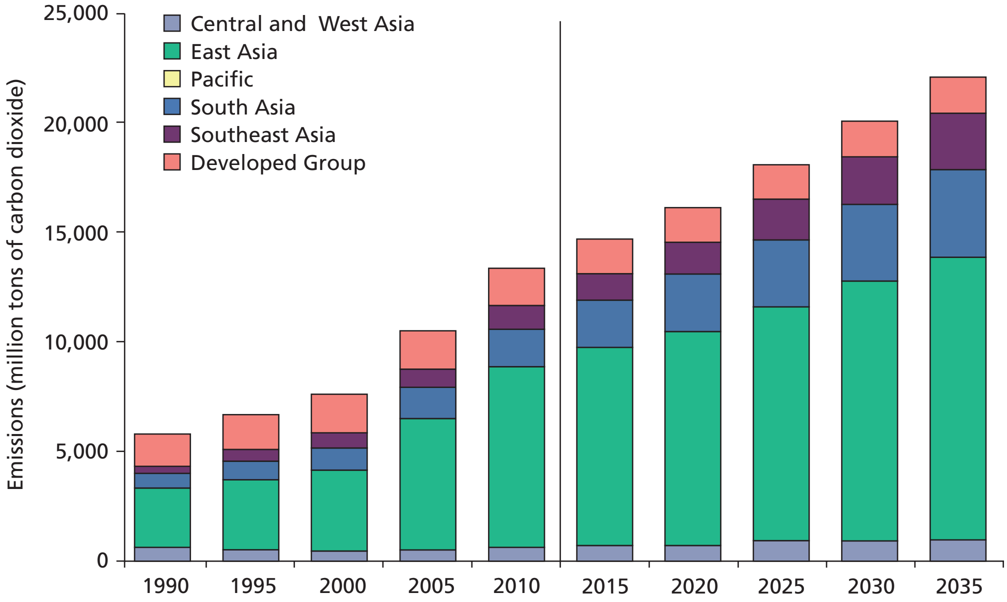

Figure 3.12 Carbon dioxide emissions by regions (1990–2035).

steppe zone, where aridization is likely to increase.

(3) In the structure of changes, the most agro-ecologically significant factor may be the instability of climatic parameters, rather than general trends.

The linkages between climate change, food security, and agriculture are apparent. Weather, the timing and amount of rain, daily average temperatures, and other climatic factors have profound effects on agricultural production and food security. Emerging evidence and research that examines the linkages and interplay between climate change, resource degradation, food security, and conflicts is expanding. However, the complex nature of the triggers for conflict and food insecurity and its relationship with climate change remain unclear and need to be study further.

3.8 Climate change and environmental toxicology: air pollution and other pollutants

Generally, fossil fuel consumption leads to major emissions of GHGs in Asia and Oceania. China (industry and transportation) and Indonesia (deforestation and emissions from forest fires) are the two biggest emitters of GHGs in the region. Fossil fuel emission accounts for about 91% of total CO_2 emissions from coal, oil, gas, and others from human sources, as shown in Figure 3.12.

GHG emissions are among the biggest contributor to air pollution in the region. The frequency of EWEs caused by climate change makes it worse. The rising temperature will enhance the toxicity of contaminants and increase the concentration of tropospheric ozone regionally as well as increasing the rate of chemical degradation. The situation is also known to accelerate pollutant formation and reactions causing changes in ambient concentrations of contaminants, including particulate matter, and leads to air pollution.

Air pollution refers to the release of hazardous substances into the air that are detrimental to human health, vegetation, buildings, and the global environment. Exposure to high levels of air pollutants can cause a variety of adverse health effects, such as an increase the incidence of respiratory diseases, lung cancer, as well as CVD (WHO 2015).

Climate change and air pollution have a complex relationship. Several studies have reported that climate change may have caused the increases in concentrations of photochemical oxidants, especially ozone, in the air (Fleming *et al*. 2018). ozone has been

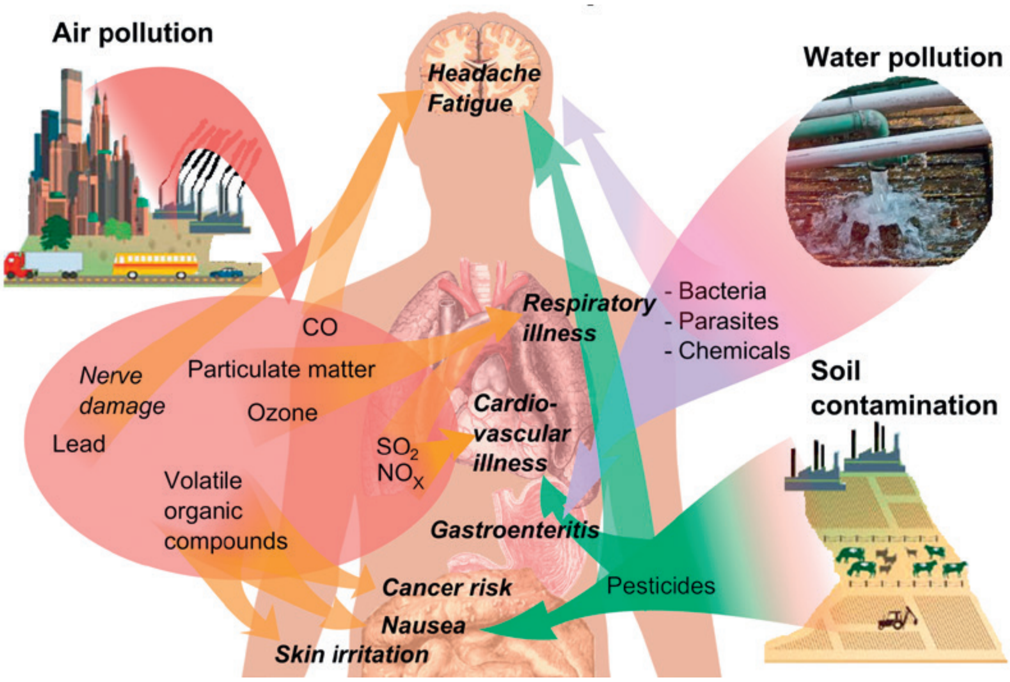

Figure 3.13 The effects of pollution on health.

found to be associated with total morbidity and mortality due to cardiovascular and respiratory diseases (Ng *et al*. 2013). A rising ozone concentration in tandem with warming may be the cause of these increases in ozone-related deaths.

The evidence for an association between airborne particulate matter and a high-temperature environment to human health is consistent. It has been reported that ambient temperatures may interact with air pollution and increase air-pollution-related health effects further. High-temperature environments may worsen the physical reactions to short-term exposure to ozone, with an increase in mortality risk, and reinforce effects due to PM_{10} pollutant concentrations, including respiratory mortality (Fleming *et al.* 2018).

However, other reports found no relationships between air-pollution-related mortality and climate change. Therefore, the current evidence is insufficient to achieve definitive conclusions (Orru *et al*. 2017).

Urban areas with dense industry and a high traffic volume are prone to have high oxidant concentrations in the surrounding air. If air pollution remains as high as it is today, warming may lead to further increases in the concentrations of oxidants, which can lead to worsening impacts on health (Fukui Prefectural Sanitary and Environmental Research Centre 2012).

The combined negative impact of climate change and atmospheric air pollution, especially in urban communities, contributes to the increase in non-communicable diseases, in particular CVDs and respiratory diseases. This is attributable to the impact of $PM_{2.5}$, which causes cardiovascular, respiratory, and oncological diseases.

In addition, short-lived climate pollutants account for mortality and morbidity cases related to air pollution. There has been an increase in the number of morbidity cases of cardiovascular and respiratory diseases. According to the results of a preliminary study, only in the case of the mortality rate is there a very weak correlation with the average annual air temperature (Yamashita and Honda 2018). Meanwhile, air pollution causes about 7 million deaths per year worldwide, eliciting an urgent need to formulate and implement strict policies, at global and local levels.

In Kathmandu, the capital city of Nepal, the population's exposure to outdoor air pollution is high, since the annual mean $PM_{2.5}$ concentration is above the WHO guideline value of 10 $\mu g/m^3$. Activities that increase air pollution also contribute to climate change. So, it is imperative for the Government of Nepal to introduce air pollution mitigation efforts not only to reduce the health burden from it but also to reduce Nepal's contribution to climate change.

In East Asia, projections of the health effects of future ozone and $PM_{2.5}$ concentrations have been reported. Using multiple SRES scenarios, projections of ozone concentrations have been made for the 2020s, 2050s, and 2090s (Lee *et al*. 2015). In all scenarios except the SRES A2 scenario, summer ozone concentrations were projected to peak in the 2020s.

In research focusing on Japan, premature mortality rates due to ozone and $PM_{2.5}$ concentrations were projected to continue increasing until the 2020s (Yamashita and Honda 2018).

Air pollution in Malaysia is unique by its nature. Similar to other countries in the Southeast Asia, Malaysia has a fair share of poor air-quality episodes: seasonal, episodic, and transboundary, observed for many years. Transboundary pollutants from neighbouring countries (especially Indonesia) include fine particulate matter from forest fires during dry seasons (between August and September) each year, now commonly referred to as haze.

Australia is normally known for its good air quality but certain communities living close to coal-fired power stations and increasingly those in urban cities are breathing bad air. The effects of the smoke haze over the summer of 2020 should be a clarion call for action on both climate change and air pollution; not only for Australians but also for the populations and future generations where Australia exports fossil fuels.

Air quality in New Zealand is generally much better than in many other countries, owing to low levels of industrial activity, low population density, and favourable meteorology. However, climate-sensitive pollutants including particulate matter and photochemical oxidants such as ozone still cause about 1,000 premature deaths a year and 1.35 million restricted activity days. It is not clear how climate change will affect levels of air pollution in New Zealand. Higher temperatures may increase levels of ozone around urban areas, especially if air-cleansing vegetation is stressed by heat and lack of moisture, as has occurred in Europe.

In Azerbaijan, climate change is already increasing the number of toxic chemicals, especially carcinogens after EWEs (hurricanes, wildfires). Increased exposure of humans to these toxic chemicals can lead to various types of cancer such as liver, breast, and lung cancers. Moreover, various air pollutants have also been shown to cause lung cancer in humans. In addition to increasing cancer risk, climate change is also affecting cancer survival. The frequencies of stomach cancer and lung cancer are greater in Azerbaijan. The high incidence of these types of cancer is recognized as a consequence of adverse changes in the environment.

The links between climate change and ultraviolet flux at the Earth's surface are complex. High-level ozone depletion has contributed to climate change across the Southern Hemisphere in the past 50 years, and in turn climate change is modifying human exposures to ultraviolet light, through time spent outdoors, migration, and vegetation cover, for example. These effects are particularly important in New Zealand, given the relatively high exposures that currently occur and the susceptibility of the population to its adverse effects, for skin cancers in particular.

As the most important global environmental risk factor for premature mortality (Watts *et al*. 2019), $PM_{2.5}$ pollution has been one of the most vital challenges facing China for years.

The ambient air pollution was responsible for around 1 million premature deaths in China around 2013. Benefiting from the toughest-ever clean-air action plan launched in 2013 and subsequent effective measures, such as strengthening industrial emission standards, upgrades on industrial boilers, phasing out outdated industrial capacities, and promoting clean fuels in the residential sector, remarkable improvements in air quality have been made in China (Zhang *et al*. 2019).

From 2014 to 2018, the medians of cities' annual average $PM_{2.5}$ concentrations for each year were, respectively, 61, 48, 46, 41, and 37 $\mu g/m^3$, dropping at least 5% annually, but still exceeding the WHO's Interim target and China's National Air Quality Standard for Grade-II (35 $\mu g/m^3$). Therefore, it was estimated that around 42% of the Chinese population lived in areas with annual mean $PM_{2.5}$ concentrations of over 35 $\mu g/m^3$, especially in and around the Beijing–Tianjin–Hebei region (the so-called '2+26' cities), Fenhe and Weihe plain, and northwest China (Maji *et al*. 2018; Yang *et al*. 2019).

There is another chain that links climate change with air pollution. Climate change may exacerbate air pollution by increasing both the frequency and persistence of weather conditions that enhance accumulation of pollutants (Horton *et al*. 2014; Cai *et al*. 2017). One study has shown that even assuming pollution emissions are held constant, over 85% of China's population may still be exposed to worsening air quality as a result of atmospheric stagnation under moderate warming (RCP 4.5) by 2050 (Hong *et al*. 2019). This implies ambitious mitigation actions could prevent future climate change from undermining efforts to reduce air pollution.

3.9 Allergies

Allergies are closely associated with climate change and air pollution. Increased temperatures contribute to higher levels of pollens and allergens in the atmosphere and extend the duration of the pollen season (spring). Alterations in the duration and intensity of pollen season affect allergic disorders such as rhinitis, conjunctivitis, airway inflammation, and asthma. Storms were found to increase pollen-related asthma attacks.

Air pollution increases the allergen properties of pollens. The presence of carbon dioxide in the atmosphere may lead to faster growth of plant species that cause allergies. Increased atmospheric carbon dioxide and higher plant growth is expected to generate greater pollen production.

It has been known that climate change causes a shift in phenological phases. As a result, seasonal allergic diseases (especially in spring) appear earlier and last longer.

In addition, it has been shown that climate change contributes to the spread of the well-known species *Ambrosia artemisiifolia*, which causes allergic manifestations in the population; not only does the distribution area of this species increase, but its altitudinal limits also expand significantly.

In New Zealand, grasses and plants are the main source of atmospheric pollen in summer and spring, and climate change has already lengthened the growing season for relevant plant species. The silver birch is now the main source of tree pollen causing allergic symptoms. By 2100, the amount released each year is projected to be roughly 8 times higher than in the early 2000s, on the basis of modelling in the northeastern USA (Zhang *et al*. 2019).

The International Study of Asthma and Allergies in Childhood found that allergies are most prevalent in developed countries such as Australia and New Zealand. However, the study also found that the incidence of asthma, rhinitis, and eczema increased steadily over the first 15-year period since the study started in 1991.

Asthma in Bangladesh is considered a significant public health issue. An estimated 11.6 million people suffer from asthma-related symptoms; 4.1 million of them are children

(Hassan *et al*. 2010). The first national survey on asthma prevalence, commonly known as NAPS-1999, found that more than 5% of the total population, as well as 7.5% of 1- to 5-year-old children, were suffering from asthma (Hassan *et al*. 2010). The study also suggested that children from low-income, poorly educated, rural and suburban communities had a higher prevalence than those from urban households.

Another study that used the International Study of Asthma and Allergies in Childhood questionnaire both in urban and in rural schools in Dhaka reported that the prevalence was 9.1% among 6- to 7-year-old children and 6.1% among 13- to 14-year-olds (Kabir *et al*. 2005). The reported prevalence was higher among male children than females (Kabir *et al*. 2005).

In Armenia, data on allergic diseases are not highlighted by the State Statistics Committee. Therefore, a direct analysis of the relationship between allergic diseases and climate change is currently not possible.

A study in Kuala Lumpur reported results of skin prick tests using pollen extracts on 200 patients with clinical symptoms of asthma. Pollen extracts of three types of grass (Bahia, Bermuda, rough pigweed) and two flowering trees (*Acacia* and *Melaleuca*) were used in the tests. Of the 29.5% asthmatics with positive reactions, 21.5% were reactive to one or more of the grass pollens, 21.5% to *Acacia*, and 7.5% to *Melaleuca* pollen. Acacia and Bermuda grass extracts were the most allergenic (Sam *et al*. 1998).

Nearly a quarter of the total population of India suffers from allergies. Asthma and upper respiratory diseases attributed to chronic allergy have affected a substantial population of the country across all age groups. Cases of allergy and atopic asthma are found to be highest in states such as Kerala, West Bengal, and Mizoram (3,000–4,000 cases per 100,000 people) followed by Andhra Pradesh, Orissa, and Assam (2,000–2,999 cases per 100,000 people).

Pollen dispersion rates have been increasing, although the amount fluctuates from year to year (Gotou 2010; Kobayashi *et al*. 2013). A variety of factors can influence the dispersion of tree pollen such as Japanese cedar, cypress, and birch in Japan. Climate change and changes in land use are two commonly cited factors. In prefectures with high pollen dispersal of Japanese cedar (*Cryptomeria*), a high prevalence of allergy to cedar has been indicated (Suzuki 2015). Some medical centres have reported an increase in rates of return visits for cedar allergy and an increase in the number of days the anti-allergenic agent needed to be administered. These changes have also had major effects on medical expenditure (Ito 2014).

In conclusion, climate change will potentially lead both to higher pollen concentrations and to longer pollen seasons, causing more people to suffer from pollen and other allergens. Pollen is an airborne allergen that can affect human health. Exposure to it and other allergens can trigger various allergic reactions including symptoms of rhinitis (also known as hay fever). People with respiratory illnesses such as asthma may be more sensitive to pollen, which has been linked to asthma attacks and increases in hospital admissions.

3.10 Forced migration and its consequences

Climate change is rarely a direct trigger for displacement or migration. It intensifies the consequences of underlying environment, social, and governance challenges to reduce resilience, exposing people to increased risks of displacement or forcing people to move elsewhere. Countries in Asia and Oceania are no exception.

Since 2008, an average of 21.5 million people have been forced to migrate each year due to disasters such as floods and droughts. It is stated that millions of people will demand asylum in Europe every year, owing to climate change, without political and economic factors. A study showed that citizens of countries with an annual mean temperature greater than 20 °C demand more asylum than those of countries with lower temperatures (EKOIQ 2019).

The top 10 migration movements in 2016 were due to climate. The countries most affected by these migrations were the Philippines, China, and India. Large-scale displacements were triggered in 2018 and 2019 (International Organization for Migration 2019). Globally, almost 272 million people moved internationally in 2019, of whom India had the largest number (72.5 million) followed by China (10.7 million) (International Organization for Migration 2019). Migration specifically due to climate change in India was noted to be 2.7 million in 2019 (DTE Staff, 5 December 2019; https://www.downtoearth.org.in/).

Owing to the climate and disasters in Turkey in the past 10 years, 275,313 people have emigrated (UNDP Turkey 2019). Although there were 58,000 refugees in Turkey in 2011, the official number of Syrian refugees in August 2019 was only nominal, amounting to 3.6 million. According to unofficial data, this number is over 5 million. In Turkey, 89% of refugees are from Syria, 4% from Afghanistan, 3% from Iraq, 1% from Iran, and the remaining 3% from other countries.

Today, with the rise in the number of asylum seekers coming to Turkey being in excess of millions, new policies are required and introduced, most notably for economic reasons. Increasing disasters caused by climate change will lead to further increases in these waves of migration (Akay 2019). The absence of a legal framework makes it difficult to determine the protection status of these people, who are called 'climate refugees'. Climate refugees, whose legal status is uncertain, can cause social tensions due to resource shortages and indirect security problems (Yılmaz and Navruz 2019). The United Nations Human Rights Committee has taken the decision that governments cannot force people to return because of the climate crisis (Vatandaş 2019).

Over the past 30 years, migration in Armenia has had the character of expatriation and been caused mainly by economic factors. In addition, there has been a steady seasonal migration in Armenia over the past 50 years. In spring and summer, a large number of men left the republic to work in other regions of the Soviet Union, and later the Commonwealth of Independent States, returning home at the beginning of winter. In recent years, a tendency has begun to manifest itself with the return of the Armenian population to their homeland, but all these processes are associated with political and economic factors. The impact of climate change on migration has not been evaluated.

A significant problem is loss of the population to migration in the Russian Federation Far East. In general, for the period from 1992 to 2002, the total population of the Northern Economic Region, Siberia, and the Far East decreased by more than 2 million people (that is, a decline of 5.5% compared with a decline throughout the country over the same period by 2.4%). Here, whereas for all of Russia the reduction was caused by a natural decline in the population as a result of the excess of mortality over the birth rate, in the northern regions of the Russian Federation Far East, the population decline accounted for a negative migration balance (Bogatov *et al.* 2021).

According to demographic predictions, the problem of the growth of the population of the northern Russian Federation Far East will remain long-term. According to some forecasts, in 2010–2050 the total population of the Russian Far East may decrease by 21.1%, and the working-age population by 42.5%.

The International Organization for Migration (2019) notes a complex and dynamic relationship between health and migration, as migrants tend to have high exposure and economic vulnerability to health risks. Despite international norms, migrants only receive basic emergency medical packages. The situation is further complicated as migrants tend to delay seeking health-care services, while health-care services face issues relating to language, cultural barriers, and resource constraints with migrants. The report emphasizes a need for strategic leadership and investment to build an alliance between migration management and the health sector. Several health effects are noted, such as the following:

(1) communicable/epidemic diseases—tuberculosis, measles, gastrointestinal illness;
(2) food insecurity—lacking a proper and nutritious diet;
(3) non-communicable diseases—obesity, high blood pressure, cardiovascular illness;
(4) hypothermia, burns, pregnancy, and delivery-related complications;
(5) mental health—insecurity feelings and non-availability of their own community members.

The rise in EWEs as a result of climate change causes involuntary displacement as well as large and complex population movements. Forced migration is often driven by loss of a sustainable livelihood at home. Environmental factors must be integrated across all areas of migration management such as prevention, preparedness, and response to displacement. The connection between migration and climate change is complex and requires new, nimble, and comprehensive solutions to the multidimensional challenges it creates.

3.11 Mental health

One of the impacts of environmental change is mental health, which has not been adequately investigated in Asia and Oceania. The immediate psychological effects of climate change usually include the psychological trauma caused by EWEs (heatwaves, flood, drought). Higher temperatures, displacement of people from homes and communities, as well as degradation of familiar environments have significant effects on mental health and well-being. The effects are not only direct, but also indirect.

Depression, anxiety, pain, psychological distress, post-traumatic stress disorder, PTSD), aggression, complicated grief, complex psychopathology, sleep disorder, sexual dysfunction, social avoidance, irritability, drug intake, and suicide are the most prevalent illnesses or symptoms of mental health.

The common impacts on mental health caused by various climate change effects are listed in Table 3.7.

Other effects may include the impact on individuals and societies, attitudes and perceptions in their daily lives, having to contend with, consider and react adequately to climate change and its consequences (World Health Organization 2013). Stress and severe mental health effects are encountered by a significant number of individuals exposed to the environment or weather-related natural disasters. Previous studies have shown that semi-traumatic experience during and immediately after a disaster is closely linked to acute stress, which is supposed to lead to the onset of PTSD (Gruebner *et al*. 2017).

PTSD is the most common psychological problem, along with anxiety, depression, and domestic violence. These psychological effects can range from simple stress to chronic stress or other mental disorders. Many of these problems are thought to be related to EWEs and heatwaves (IWGCCH 2010).

The National Institute of Mental Health in Bangladesh conducted the National Mental Health Survey with support from the WHO. The prevalence of mental health disorders in the country was 16.8% among adults aged 18–99 years. For children aged 7–17 years, the prevalence was 13.6%. The study further indicated that 92.3% of adults and 94.5% of children diagnosed with psychiatric disorders do not get treatment. Another important finding of the study is that the main avenues of treatment are private clinic of psychiatrists, followed by health facilities run

Table 3.7 Common impacts on mental health caused by climate change effects

Climate change effect	Impacts to human health
High temperature	• Makes people tired, irritable, and even appear insane, which could cause confusion, accident, fire, crime, and other incidents. • Attribute risk factor for psychotic episodes. • Increase risk of suicide. • Often causes anxiety disorders among mental health diseases.
Extreme heat	• The stress causes many problems from heart attacks, temporary loss of consciousness, to traffic accidents. • Increased daily visits to local residents for mental illness.
Heatwaves	• Increased daily visits to local residents for mental illness. • Age, occupation, home address, and marital status may be related to the change in prevalence of mental illness during periods of heatwaves (China).
High humidity	• Stimulates a feeling of restlessness for those with panic disorder, and the frequency of attacks may increase. • Increases problems with anger control issues. Research has shown that many social events coincide with summer or hot weather, and crime rates also increase. • Many people increase alcohol or drug use while on holiday, and the holiday season can be risky for addicts or patients who are still being treated for easy access to alcohol or drugs (Denizgil 2018).
EWEs	• Flood and water-logging disasters threaten people and properties, the safety of residents in disaster-stricken areas, and cause varying impacts on mental health. In Jiangxi Province, nearly half (41.69%) of the victims had psychological reactions in varying degrees while 15.06% had more serious problems such as PTSD, anxiety, depression, and domestic violence (Ming *et al*. 2012). • Increased rates of suicide. • Loss caused by droughts affecting farmers and people living in remote areas—the helplessness, inconvenience, living conditions, and disappointment at the impact on their incomes and living standards (Li *et al*. 2013; Yüksel *et al.* 2018).

by the government and other physicians with different specialties.

With more than half a million men, women and children lost to disaster events between 1970 and 2005, Bangladesh is among those top listed countries in the world affected by climate sensitive natural disasters (Dankelman *et al*. 2008). Yet, surprisingly, the topics of mental and climate are almost absent from national, academic, and political discourses. The severity of this issue demands extensive research coupled with a strong presence in national, political, and environmental agendas.

To conclude, the effects of climate change on human health are not only direct but also indirect in the short term or long term. The delay in studies on climate change and mental health consequence is an important aspect. Lack of literature is perhaps due to the complexity and novelty of this issue. It has been shown that climate change acts on mental health with different timing and differ greatly – some psychological disorders are common and others more specific in relation to atypical climatic conditions.

The consequences of exposure to extreme or prolonged weather-related events can also be delayed, encompassing disorders such as PTSD. Moreover, climate change also affects different population groups who are directly exposed and more vulnerable in their geographical conditions, as well as a lack of access to resources, information, and protection.

3.12 Vulnerable populations and regions in Asia: differential exposure, differential vulnerability, and differential consequences

The IPCC defines vulnerability as a function of exposure, sensitivity, and adaptive capacity (IPCC 2001). Climate change will affect everyone but some of its effects are more prominent on some subsets of populations that are particularly vulnerable to the risks of heat-related illness and death than others. The reasons for these are related to individual conditions, the level of exposure to hot weather and heatwaves, and the ability to adapt to hot weather conditions (Stafoggia *et al*. 2006; Matthies *et al*. 2008).

Moreover, there is another influence in determining the vulnerability in Asia and Oceania such as geographical factors, socio-economic circumstances, as well as the age and health status of individuals or communities.

3.12.1 Geographical factors

East Asia (China, Japan, the Republic of Korea) and South Asia (India, Nepal, Pakistan, Bangladesh) are among the most vulnerable regions because of their highly variable topography and geographical factors.

Vulnerable regions are affected differently by natural disasters related to climate change. For example, vulnerable populations exposed to extreme heat are more concentrated in eastern, southern, and central China, which have the most densely populated cities. The heat effect is lower in cities with more green spaces and higher rates of ownership of household air conditioning (Ma and Sood 2008).

Nepal lies at the Third Pole[22] of the world, increasing its exposure while its high dependency on natural resources and agriculture for livelihoods increases its sensitivity (Piya *et al*. 2019). Nepal also has low adaptive capacity according to human development indicators such as life expectancy, income per head, and literacy. The country is considered underdeveloped (Badu 2013). Apart from natural disasters, exposure to infectious diseases related to climate change has also been increasing in recent years. For instance, there has been a southward trend in dengue epidemics. Some regions may have multiple health risks associated with climate change, and these risk factors may even occur simultaneously, such as typhoons combined with floods, or the high temperatures encountered with wildfires.

In the Russian Federation Far East, the gradual withdrawal of Russians from the north and the reorientation to the shift method of work in parts of its territory reflect the global tendency to develop the polar regions. January temperatures in the entire territory of the Russian Federation Far East are below –16 °C, which correspond to the second and third degree of harmfulness for outdoor work in calm weather according to the hygienic classification of labour[23] (Bogatov *et al.* 2021).

Climatic risk factors affecting the health of the population of the Russian Federation Far East form two types of bodily response: (1) immediate, within hours or days; and (2) extended, for weeks or months (seasons). Throughout the entire territory, mortality in the winter months is higher than in summer by an average of 2%. These differences are mainly determined by an increase in the level of respiratory diseases in the cold season. They range quite significantly: from 48.8% in September to 145.6% in January.

The mortality rate from diseases of the circulatory system coincides with the general seasonal fluctuation in mortality: a maximum number of cases is observed in winter (29%) and spring (26%), and a minimum in summer (19%). These differences should be considered when conducting bioclimatic predictions and working on the prevention of meteotropic reactions in patients.

3.12.2 Socio-economic circumstances

Numerous documents have reported that the risks of heatstroke disorder or heatstroke death are related to individual socio-economic

[22] 'The Third Pole' refers to the Himalayan-Hindu Kush mountain range and the Tibetan Plateau (Dhimal *et al*. 2015).
[23] Industrial hygienics is the science of protecting and enhancing the health and safety of people at work and in their communities. Health and safety hazards cover a wide range of chemical, physical, biological, and ergonomic stressors.

status (Macnee and Toka 2016; Kotani *et al.* 2019). People with lower socio-economic status and those having certain ethnicities, occupations, and education are more closely linked to heat-related health effects. Outdoor workers and people who perform heavy physical duties (constructors, including road constructors, farmers, and others), migrants, and other marginalized groups are the most vulnerable in terms of the impact of EWEs.

The urban population is vulnerable owing to the combination of the impacts of climate change and air pollution that cause diseases of the cardiovascular and respiratory systems.

Poor housing quality, long flagged as an urgent social concern in New Zealand, is also a risk factor for climate-related health threats. Homeless people lack access to temperature-controlled or structurally safe housing, and are often excluded from other resources and services, including disaster preparation and responses. In Armenia, populations in rural settlements with poor water quality, sanitary facilities, and personal hygiene, and those who are in direct contact with natural landscapes (because of their occupation or for other reasons) or with natural products, are included in the risk groups susceptible to natural foci of infections, especially dangerous ones.

In the Russian Federation Far East, such harsh areas overlap with the main settlement zone of the country and include cities with populations of 1 million or more (Omsk, Novosibirsk, other major cities). Uncomfortable living conditions form a chronic pathology of the population, leading to temporary and permanent incapacity to work and forming high mortality rates. These weather changes, typical of the Russian Federation Far East, disrupt the dynamic balance between the body and the environment, leading to various functional disorders and subsequently to diseases (Bogatov *et al.* 2021).

Turkey is full of migrants and refugees who escaped from war and were forced to migrate owing to disasters such as floods and drought. Most of these refugees live in camps in southeast Anatolia and are vulnerable to climate change and epidemic diseases. In these camps, there is an increase in diseases such as tuberculosis and measles. In addition, the incidence of some infectious diseases, such as aftosa[24], which is more common in immigrants, is gradually increasing.

3.12.3 Age and health status

A review of the literature has shown that the elderly constitute the largest defined group at risk of dying from heatwave events (Kovats and Hajat 2008; Matthies *et al.* 2008) The elderly usually have comorbid conditions and changes in physiological responses that lead to decreased heat tolerance (Kuzuya 2013). Environments with prolonged extreme heat have been linked to the increasing trend in the number of elderly people with heatstroke (Fujibe 2013), with a high risk of symptom onset in domestic environments including bedrooms (Kondo *et al.* 2013), and out-of-hospital cardiac arrests (Yamazaki and Michikawa 2017).

For elderly people with respiratory diseases, sleeping in environments with extreme heat has been linked with dyspnoea and deterioration of their physical condition (Kaido *et al.* 2017). A high proportion of elderly patients with heatstroke are transported by ambulance in Japan (Fire and Disaster Management Agency 2018).

Malaysia is also an ageing society. In 1970, only 3.3% of the population were aged 65 years or older; in 2017 the number rose to 6.2% and it was predicted to increase to 14.5% by 2020. Owing to the increasing proportion of vulnerable people in the population, Malaysia may see more heat-related health issues in the future.

[24] Foot and mouth disease, also called hoof and mouth disease or aftosa, is a highly contagious viral disease affecting practically all cloven-hoofed domesticated mammals, including cattle, sheep, goats, and pigs.

Infants and children are sensitive to the effects of high temperatures because of the differences in their metabolism and their reliance on others to regulate their thermal environment. The same is true for expectant mothers. There is limited evidence examining the vulnerability in children, pregnant women, and those with comorbidity who might be susceptible to environments with extreme heat.

People with pre-existing medical conditions have been linked to increased risks of death and illness due to heat. Medication can also aggravate heat-related illness. People with high bodyweight and chronic conditions such as diabetes have lower tolerances to heat. The prevalence of these conditions is very high in New Zealand: the country is ranked second or third in the world for the frequency of adult obesity and for diabetes, and about 20% of those aged over 65 meet the diagnostic criteria for diabetes.

Malaysians have also become unhealthier. The National Health and Morbidity Survey 2019 report shows the prevalence of diabetes mellitus in adults increased from 11.2% in 2011 to 13.4% in 2015, and the prevalence of hypercholesterolaemia among adults also increased from 35% in 2011 to 47.7% in 2015. The trends for overweight, obesity, and abdominal obesity continued to rise from 2011 (29.4%, 15.1%, 45.4%) to 2015 (30.0%, 17.7%, 48.6%), respectively. More people are also migrating to urban centres, whereby the percentage constituting the urban population has increased from 35.8% in 1980 to 70.9% in 2010.

As a summary for the vulnerability of populations and regions in Asia and Oceania to climate change effects, some groups are more vulnerable than the others. Children, the elderly, and people who have pre-existing health issues are particularly vulnerable to the impacts of climate change. People who live in rural areas are exposed to high health risks due to poor sanitation, pollution, malnutrition, and lack of clean drinking water. Similarly, people who with lower socio-economic status and those having certain ethnicities, occupations, and education are more closely linked to heat-related health effects.

3.13 Fertility

The long-term effects of climate change on health and fertility often get ignored. Several factors (independently or in combination) are silently causing the decline in the overall fertility rate in Malaysia. Malaysia has observed a declining trend in the total fertility rate over the past three decades.

The total fertility rate per woman aged 15–49 years has been declining from 4.9 babies in 1970 to 1.8 babies in 2018 (Mahidin 2019). In fact, since 2013, the recorded national total fertility rate has been below the replacement level of 2.1, which is alarming. This suggests that the average number of babies born per woman in the country does not meet the number required to replace herself and her partner in the population, as summarized in Figure 3.14.

Considering the high importance of reproductive health in the propagation of a nation's population, it is crucial to comprehend how climate change is affecting fertility parameters. Previous studies had suggested links between socio-economic factors, ethnicity, and fertility rate (Govindasamy and DaVanzo 1992; Tey 2009). While intermediate variables are important in explaining differences and the reduction in fertility status in Malaysia, there is a serious lack of research on the subject.

There are certain silent factors such as the chronic effects of global warming on health and fertility (Hanna and Spickett 2011). The reproductive tissues function only within a certain temperature range. Thus, when the ambient temperature exceeds that critical temperature, it adversely affects reproductive functions through common mechanisms of gonadal heat shock, oxidative stress, and alterations in the endocrine milieu. Heat stress caused by environmental as well as occupational factors can lead to chronic illnesses and even death, from the after-effects

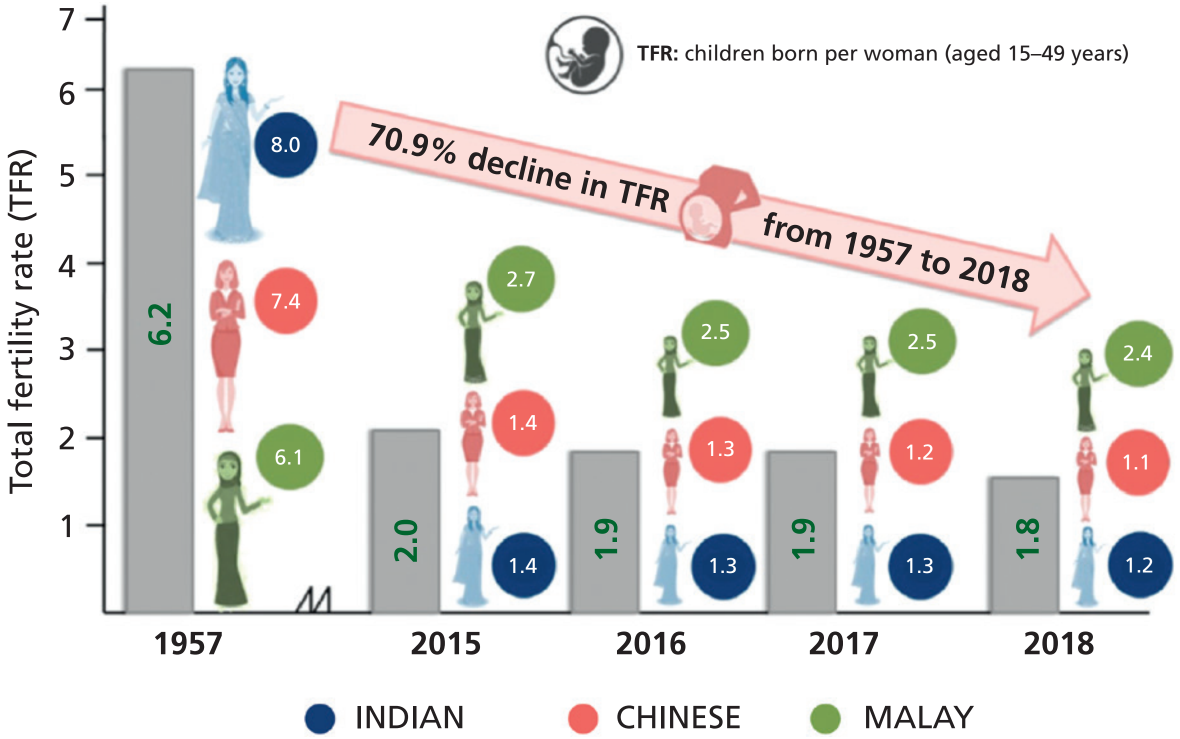

Figure 3.14 Total fertility rate (TFR) among the three major ethnic groups in Malaysia (Department of Statistics 2015).

of heatstroke (Thonneau *et al.* 1998; Mackay 2008).

The link between climate change and fertility is depicted in Figure 3.15.

3.14 Mapping the future: tipping points and existential risks

Climatic indicators combined with ecological indicators provide more significant predictions than individual factors. Climatic factors can intensify the impact of some ecological factors (the synergism phenomenon) and lead to a better result. This method allows prediction with sufficient accuracy of the epidemiological situation on the basis of a combination of various environmental factors. With the expansion of the set of factors, the merit of the prediction increases.

On the whole, tipping points in climate change for Asia and Oceania are indirectly related to the European ones, which have a cascading effect on the following:

(1) extreme environmental heat stress;
(2) warm southern oceans;
(3) disrupted Asian monsoons;
(4) collapse of Amazon rainforest.

Once these tipping points have been crossed, we can only prepare for unpredictable climatic changes and catastrophes.

On the basis of ensembles of high-resolution climate change simulations, Im *et al.* (2017) projected that the extreme wet-bulb globe temperature in South Asia could cross the critical threshold in some areas by the late 21st century if the current emission of GHGs continues. South Asia is considered to be particularly vulnerable without mitigation because of its high population density, poverty, and vulnerability.

The warming of oceans and the changes in ocean circulation systems have been predicted to reawaken an El Niño/La Niña type of climate phenomenon in the Indian Ocean with wildly see-sawing weather patterns leading to unpredictable monsoon pattern.

The National Adaptation Plan on Climate Change of India recognizes a rise of 0.40 °C

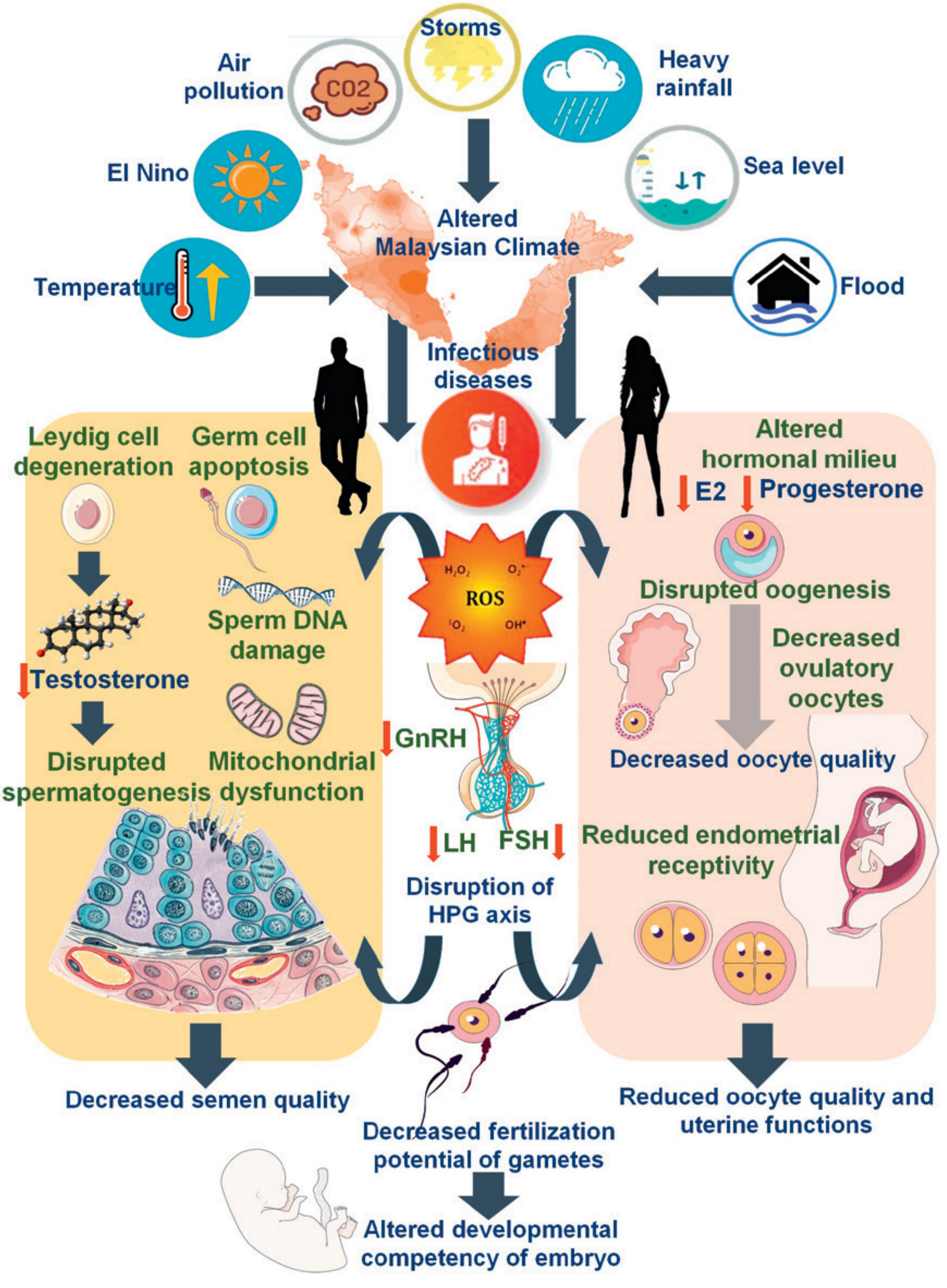

Figure 3.15 The link between climate change and fertility.

in the surface air temperature in the past century wherein the warming trend is noted along with west coast, the central part, the interior parts of the peninsular, and northeastern parts of India; and a cooling trend is witnessed in the northwest and southern parts of India.

In view of the frequency of EWEs, the Japanese Government recognized the 'climate crisis' as a threat to the basis of human survival in a white paper (MOE 2020a). The report extrapolated a threshold beyond which there could be a catastrophic change in the state of human survival and society. However, such a threshold carries a limited interpretation of public health because if the rise in temperature exceeds the physiological capacity of the human body, individuals may usually respond with a change in lifestyle and social systems.

In partnership with The *Lancet* Countdown, University College London, and the *Medical Journal of Australia*, Australia was the first country to produce its own national Countdown assessment report in 2018. The report found that, overall, Australia is vulnerable to the impacts of climate change on health, and that policy inaction in this regard threatens Australian lives.

The 2019 report presents the first annual update of this assessment tracking Australia's engagement with, and progress on, this vitally important issue. The Australian Countdown tracks progress on health and climate change in Australia across 31 indicators divided into five broad sections: climate change impacts, exposures, and vulnerability; adaptation, planning, and resilience for health; mitigation actions and health co-benefits; finance and economics; and public and political engagement.

According to the climate change models under the RCP 8.5 scenarios, the average annual temperature in Armenia will rise by 3.1 °C by 2100 and reach 10.2 °C. The amount of precipitation will decrease by 33 mm and amount to 543 mm per year. In summer, the average air temperature in the lower zones (up to 1,000 m) can reach up to 27 °C and above, and precipitation is expected to decrease by approximately 12%. Such serious changes will certainly affect all sectors: water resources, agriculture, natural ecosystems, human health, infrastructure, and industry.

These forecasts require an immediate response from decision-makers for the development and implementation of new strategies and national programmes. All this can be done; unfortunately, however, this is likely to be too slowly both for objective and for subjective reasons. Objective reasons include the difficult economic situation in Armenia, which is associated with the reluctance to change something in the existing system (in agriculture, public health, industry, etc.). Subjective reasons include the fact that climate change is not taken seriously by decision-makers.

3.15 The influences of development pathways towards future scenarios

The SDGs will have a direct influence in shaping development pathways. Current norms of development are likely to enhance climate change impacts, not only affecting infrastructure, labour productivity, and gross domestic product, but also indirectly affecting the population through reduced income, health challenges, as well as loss of traditional work and opportunities.

In most of the development scenarios, the impacts of climate change are not just inevitable but significant. However, owing to high uncertainty in the development pathways, the projection of future scenarios, mainly in the socio-economic domains, is found to be problematic and indeterminate (ADB *et al*. 2003).

Currently, various strategies and action plans are being implemented or are being developed in Asia and Oceania, which necessarily take into account the effects of climate change. This is especially evident in strategies and action plans related to international environmental conventions (among others: IPCC; Paris Agreement; Framework Convention on Climate Change; Convention on Biodiversity; Convention to Combat Desertification).

With correct implementation of the planned actions, it will be possible to avoid the serious economic and environmental consequences of climate change, adapt to new conditions, and reduce public health risks.

Priority factors and actions that can provide scenarios for reducing the incidence of the effects of climate change on the population include the following.

- Preservation of natural conditions necessary for human life and further development of production and culture, the development of ‘green technologies’ in industry, protection of the population from natural disasters and natural hazards.

- Formation of scientific and technical groundwork for the creation of high-tech innovative products (methods and means of diagnostics, prevention, and treatment of infectious diseases), ensuring biological safety, reducing infectious diseases.

- Intensification of expeditionary activities to monitor the state of ecosystems and biotopes in the Russian Federation Far East and the border areas of Southeast Asia, biological objects, natural reservoirs of pathogens, and foci of infectious and parasitic diseases.

- Creation of a technological platform for a quick response and scientifically grounded risk management of dangerous epiphytotic, epizootic, and epidemic situations of natural focal genesis using new molecular genetics and information technologies.

- Assessment and forecasting biological safety in the Russian Far East and Southeast Asia, forecasting the formation of secondary natural foci of infectious and invasive diseases.

- Comprehensive study of molecular biological, genetic, ecological, and epidemiological characteristics of pathogens of infectious and parasitic diseases, relevant to the Far East.

- Implementation of breakthrough directions in the fight against infectious diseases aimed at finding and studying new means for the prevention and treatment of infectious diseases: antimicrobial drugs with new mechanisms of action (bacteriocins, antimicrobial peptides of marine origin), drugs alternative to antibiotics (inhibitors of bacterial virulence, inhibitors of the collective behaviour of bacteria), broad-spectrum antiviral agents.

- Development of new technologies for epidemiological, epizootic, microbiological, and molecular genetic monitoring of pathogens of viral and bacterial infections, endoparasites, including monitoring of pathogens of natural focal infections associated with blood-sucking mosquitoes, ixodid ticks, monitoring of plant viruses in natural and cultural phytocoenoses, monitoring of viruses associated with wild birds, monitoring of endoparasites of domestic animals, etc.

- Harmonization of methodological approaches to the indication and identification of biological pathogenic agents of pathogens of infectious diseases in humans and animals according to Russian and international standards.

- Creation of geographic information systems on infectious and natural focal diseases of humans, and agricultural and forest pests. Creation of an information environment for a quick response and scientifically grounded risk management of dangerous epiphytotic, epizootic, and epidemic situations of natural focal genesis. Development of criteria for assessing the degree of danger of ballast waters and invasive species, and the role of bio-invasions of alien species for the sustainability of ecosystems in Far Eastern seas; assessment of the ecological consequences of extinction and the invasion of species.

- Assessment of the likely consequences of harmful algal blooms and the impact of their toxins on marine communities and human health in Far Eastern seas.

- Development of technology for monitoring and ensuring toxicological safety of sea areas and products of marine origin.

4 Main adaptation and mitigation options

Overview

1. The Asia and Oceania region needs an integrated mitigation and adaptation strategy tailored to its own needs to combat the effects of climate change on human health, society, and the environment after implementing international agreements (the United Nations Framework Convention on Climate Change, the Paris Agreement, the Kyoto Protocol).

2. Developing countries (especially those in South Asia) are facing difficulties in implementing mitigation and adaptation plans for several reasons (economic, capacity, and lack of trained human resources) compared with developed countries.

3. Several case studies are presented to show the implementation of the plan in various countries.

Integrated strategies for adaptation and mitigation are essential. Specific opportunities for adaptation and mitigation are described in this section in a spectrum of Asian and Oceania countries. These are additional measures taken by each country after implementing international agreements such as the United Nations Framework Convention on Climate Change (1995), the Kyoto Protocol (2000; https://unfccc.int/kyoto_protocol), the Doha Annex (second period of implementation of the Kyoto Protocol), and the Paris Agreement (UNFCCC 2015).

For developing nations, climate change mitigations place a heavy burden on their already strained economies. By the time of the Paris Agreement (2015), developed nations had committed to invest in various renewable energies and other mitigation projects in their own countries. As part of the agreement, concessional loans and grants can also be raised by recipient nations from multilateral development banks for climate-related activities.

4.1 National adaptation plans for climate change and health

In general, most Asian National Adaptation Plans for climate change and health (CC&H) incorporate the measures included below:

(1) to accumulate scientific data and knowledge on climate change to fill evidence gaps[25];
(2) to increase evidence-based research and study capacity related to CC&H to identify the most pressing health threats from climate change;
(3) to provide scientific information (meteorological, medical, geographical), warnings, and alerts, for prevention and adaptation by cooperating with relevant ministries and agencies;
(4) to raise awareness among the general public, policy-makers, and health-care providers in addition to promoting efforts by companies and local governments;
(5) to provide structured surveillance (monitoring) and reporting systems;
(6) to strengthen the capacity of the health-care system (including health preparedness and response) to cope with the health effects of climate change;
(7) to reinforce health preparedness and response at national, state, and district levels.

4.2 Approaches to adaptation and mitigation

Adaptations to climate change have enabled steady progress in human health. The main approaches to tackle the effects of climate change are improving the abilities of governments to provide services and management, as well as promoting

[25] Among the gaps are climate data to identify and classify disease patterns, responses to VBDs, ecological studies of pollutants and pollens, etc.

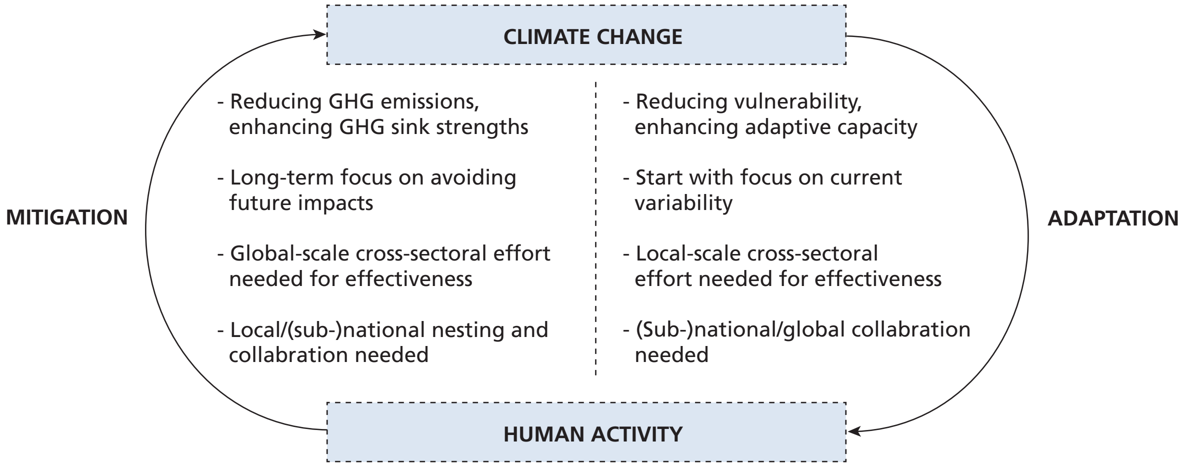

Figure 4.1 An overview of adaptation and mitigation initiatives to climate change with human activity.

Table 4.1 National Adaptation Plans in Asia and Oceania

Country	National Adaptation Plans
Armenia	Does not yet have a national strategy or a National Adaptation Plan for climate change in the health sector. In recent years, only the law on 'Ensuring the Sanitary-Epidemiological Safety of the Population of the Republic of Armenia' (adopted in 1992) was amended on 21 March 2018. The concepts of prevention of diseases and epidemiological monitoring were defined. The content and functions for the fulfilment of inspection control in the human health sector were also outlined.
Australia	To date, only Queensland has implemented a comprehensive climate change adaptation plan. Other states and territories make small reference to health in their climate change adaptation plans. Tasmania is in the process of developing its health adaptation strategy. Western Australia announced an inquiry into the impacts of climate change on health to be conducted under the Public Health Act 2016. A final report will be presented to the Western Australia Minister for Health by March 2020. In addition, the Climate and Health Alliance has produced a Framework for a National Strategy on Climate, Health and Well-Being for Australia.
Azerbaijan	Azerbaijan has not made quantitative commitments to reduce GHG emissions from the Kyoto Protocol. However, the country has taken several important steps in recent years, including the introduction of low-carbon, energy-efficient, renewable energy and waste management technologies, as well as forest expansion and the reduction of deforestation. In addition to national mitigation initiatives, Azerbaijan successfully cooperates with several international organizations through the implementation of various projects. Thus, more than 30 projects related to climate change mitigation technology and capacity building have been implemented. To achieve its SDGs, the National Coordinating Council for Sustainable Development of Azerbaijan was established in 2016. The country's mitigation and adaptation strategies for climate change are reflected in the following long-term State Programs: (1) State Program on the Use of Alternative and Renewable Energy Sources (2004); (2) State Program on Socio-Economic Development of the Region in the Republic of Azerbaijan for 2008–2015; (3) State Program on Poverty Reduction and Sustainable Development in the Republic of Azerbaijan for 2008–2015; (4) Strategic Roadmap for Agricultural Production and Processing in the Republic of Azerbaijan (2016).

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Table 4.1 (*continued*)

Country	National Adaptation Plans
Bangladesh	In 2011, the Government of Bangladesh adopted the National Health Policy. The policy comprises a few major sections as 3 broad goals, 19 specific objectives, 16 principles and major tasks, 18 challenges, and 39 specific tasks (NHP 2011). Some publications on climate change have identified health as an important factor: (1) The National Adaptation Programme of Action in 2005 or National Adaptation Plan was prepared by the Ministry of Environment and Forest, as a response to the UNFCCC convention; (2) Climate Change Cell, under the Department of Environment, was formed later in 2006; (3) Bangladesh Climate Change Strategy and Action Plan (BCCSAP) 2009, by the Ministry of Environment and Forest. As a developing country, with its limited resources, Bangladesh has adopted all means of instruments as medical facilities, education, training, and good governance to ensure health facilities for all people in the country.
China	Until now, there was no standalone Health National Adaptation Plan but national policies since 2007 in response to climate change have included health implications to some extent. China's National Strategy for Climate Change Adaptation has taken to protecting human health as a priority for adapting to climate change. Provincial health and climate change plans have been declared in Guangdong, Shanghai, and Sichuan according to surveys (Cai *et al.* 2021).
India	National Action Plan on Climate Change in 2008. There were eight missions in this plan, although health was not one of them. Later, four new missions including a Health Mission were added to the NAPCC in 2014. The Ministry of Health and Family Welfare appointed a National Expert Group on Climate Change and Health, which drew up a National Action Plan for Climate Change and Human Health in 2018. It emphasises the integration of health mission with other national missions. There are 12 national missions relating to climate change: (1) National Mission on Sustainable habitat; (2) National Mission for Sustaining the Himalayan Ecosystem; (3) National Mission for Sustainable Agriculture; (4) National Solar Mission; (5) National Mission for Enhanced Energy Efficiency; (6) National Water Mission; (7) National Mission on Strategic Knowledge for Climate Change; (8) National Mission for 'Green India'; (9) National Mission on Health; (10) National Mission on 'Waste to Energy Generation'; (11) National Mission on India's Coastal areas; (12) National Wind Mission.
Indonesia	There are more than 9,000 primary health-care facilities and 2,500 hospitals all over Indonesia. Five years ago, there was effort to transform the manual system into an ICT-based system at many health-care facilities across Indonesia. Thousands of health-care facilities implemented electronic medical records and information systems, and the number is growing significantly. Digitalization of health facilities is also an indicator for health-care accreditation, as well as improving convenience and cost and time efficiencies. By using an online appointment system, patients are able to plan their movements and no longer need to wait unnecessarily long hours before seeing physicians. The procedure of getting medications is improved by sending electronic prescriptions to pharmacies, allowing faster processing. As a result, health-care facilities have significantly reduced the use of paper that previously contributed to massive deforestation in the country. There is now less spent on paper and reduced space necessary to manage paper-based medical records.

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Table 4.1 (*continued*)

Country	National Adaptation Plans
Japan	In 2016, A-PLAT[26] was launched by the National Institute for Environmental Studies, Japan, to disseminate information related to sectoral impacts and adaptations, and to support the formulation of adaptation plans by local authorities and others through the cooperation with relevant ministries and agencies. A-PLAT also shares the information on existing adaptations conducted by the government, local authorities, and private companies. In 2018, The Climate Change Adaptation Act in Japan was promulgated in June and enforced in December. National Adaptation Plan was approved by the cabinet in November 2018. It describes adaptations in seven sectors (Cabinet Decision 2018). Adaptations to climate change in the health sector are explicitly for heat-related risks (excess mortality and increase in the number of patients with heatstroke), infection (dengue fever), and others (risks induced by oxidant air pollution). In 2019, AP-PLAT[27][31] was formally launched by the Ministry of the Environment aided by the National Institute for Environmental Studies with similar objectives as A-PLAT but covering the Asia Pacific region.
Malaysia	According to Malaysia's Nationally Determined Contribution submitted to the UNFCCC in November 2015, Malaysia is committed to reducing 45% of GHG emissions per unit of gross domestic product by 2030, relative to its emission intensity in 2005. This target would encompass a 35% reduction on an unconditional basis, and a further 10% reduction subject to receipt of climate financing, technology transfer, and capacity building from developed countries (MESTECC 2018).
Nepal	In recent years, Nepal's health sector has started to consider climate change as an important factor when drafting plans and policies. In 2006, the Nepal Health Research Council, the health research body of the government of Nepal, along with the WHO Nepal, declared climate change as a major research area. This declaration facilitated the first national workshop on CC&H in December 2007. The workshop identified the need to generate more scientific evidence on the links between CC&H and involved over 80 stakeholders including government officials and policy-makers, researchers, academics, journalists, and members of civil society. Since the workshop, numerous national-level studies on CC&H have been conducted in Nepal, with support from the WHO. Furthermore, both the environment and health sectors have incorporated CC&H impacts into their policies as well as implementation plans. More importantly, National Adaptation Plans such as the National Adaptation Programme of Action to Climate Change and the Health-National Adaptation Plan were drafted in 2010 and 2017, respectively, to introduce adaptation and mitigation measures to relieve the burden of climate change on the social, economic, and health sectors. The Government of Nepal has started to introduce and implement the following initiatives: National Adaptation Programme of Action to Climate Change (2010); National Framework on Local Adaptation Plans of Action (2011); National Health Sector Programme - Implementation Plan II (2010–2015); National Health Sector Implementation Plan (2016–2021); Climate Change Policy 2011, revised 2019; National Health Policy 2014, revised 2019; Intended Nationally Determined Contributions 2016; Nepal National Adaptation Plan 2015; Nepal Development Vision 2030 (concept paper) 2011; Health National Adaptation Plan: CC&H strategy and action plan (2017–2022).
New Zealand	Climate change assessments in the past were mainly undertaken by local authorities, and demonstrated marked socio-economic and spatial variations in vulnerability to ill-health caused by extreme weather. The first national climate change risk assessment was published in late 2020, and it is intended this will form the basis of a National Adaptation Plan, as required by the Zero Carbon Act of 2019.

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[26] The Climate Change Adaptation Information Platform, https://adaptation-platform.nies.go.jp/.
[27] The Asia Pacific Climate Change Adaptation Information Platform, https://ap-plat.nies.go.jp/.

Table 4.1 (*continued*)

Country	National Adaptation Plans
Pakistan	Recent initiatives by the Government of Pakistan for climate change adaptation and mitigation include the following. (1) Clean Green Pakistan Index, which includes the programme to plant 10 billion trees in 2019–2023. (2) Prevention of sea intrusion in Thatta, Sindh. (3) EHSAAS Program[28], the objective of which is to reduce inequality, invest in people, and lift lagging districts. (4) Billion Tree Tsunami. This is one of the popular initiatives taken by the Government of Pakistan. The programme has been well received by the global community.
Republic of Korea	According to the Framework act on low carbon, green growth Article 48 (Assessment of Impacts of Climate Change and Implementation of Measures for Adaptation) ', the 1st (2011–2015) and 2nd (2016–2020) National Climate Change Adaptation Master Plan were implemented. The 3rd policy (2021–2025) was announced in December 2020. The vision of this policy is the realization of a climate-safe country with citizens. The goals of the plans are the following: to enhance the climate resilience of all society in preparation for a rise of 2 °C in global temperature; to promote science-based adaptation by enhancing climate monitoring and prediction infrastructure; to achieve the mainstreaming of climate change adaptation. Actual policies include improving adaptability to climate risk; climate change monitoring, prediction, and evaluation; achieving the mainstreaming of climate change adaptation.
Russian Federation Far East	In 2019, the Ministry of the Russian Federation for the Development of the Far East and the Arctic introduced the National Program for the Development of the Far East up to 2025 and for the long term to 2035 for consideration by the Government of Russia. The Program consists of three sections: economy, infrastructure, and social block. The following main directions of social development were defined in the National Program: development of the health-care system, education and science; ensuring accessibility to transport; creating promising conditions for the birth of children; building housing and creating a comfortable urban environment; developing culture and sports. The National Program is currently being finalized.
Turkey	A Climate Change Coordination Board, under the coordination of the Ministry of Environment and Urbanization, has been established to perform studies in this field. All policy work is coordinated by this Board. The National Program and Action Plan for Reducing the Negative Effects of Climate Change on Health were launched in 2010 and approved on 21 January 2015.

the establishment of health monitoring, investigation, and assessment of risk systems.

There are several general points to be made for effective adaptation and mitigation in every country in Asian and Oceania, before exemplifying specific case studies in later sections.

(1) The importance of communication across different sectors—essential for multi-sectoral impact assessment and adaptation/mitigation planning.
(2) Pilot surveillance and monitoring systems as early-warning systems for heatwaves and health risk factors—monitoring dynamic changes in epidemic situations and their influencing factors, an important first step for evidence-based policy-making, the data can be used to plan and prioritize measures to minimize the impacts on health, to identify vulnerable populations, and to formulate public health preparedness and rescue mechanisms for certain diseases that are closely related to climate change (for example Middle East respiratory syndrome, H7N9 avian influenza, dengue fever).
(3) Research and study on the prevention and control of climate-change-related diseases.

[28] The program has provided the largest cash support (USD900 million) to more than 12 million people affected by the COVID-19 lockdown in the country.

(4) Enhancement of health-care systems—infrastructure, sustaining health services and its personnel, preparedness and response plans, etc.
(5) Social transformation—as a counteraction against pandemics (for example COVID-19), to help promote awareness and controls, and to improve water quality, sanitation, and hygiene levels.
(6) Development of technologies for adaptation and optimization of the agricultural sector.

Apart from these general points, each country has its own approaches which are summarized in Table 4.2.

Equity is essential for mitigation and adaptation approaches. Without the participation of the people, policies will be ineffective. Numerous behavioural and physical limitations have to be considered when addressing mitigation and adaptation strategies. Movement of people, for instance, is largely governed by the availability of livelihood. Loss of homes and livelihood due to EWEs or slow change in living conditions will drive people away from homes and into new, unfamiliar areas with little preparation to host large population migrations. Sanitation infrastructure and improved drinking water sources are already well known as nature-based solutions for mitigation and adaptation actions.

More recently, studies have begun to provide evidence on linkages between the natural environment and human health, including multiple health outcomes and potential confounding factors.

Table 4.2 Approaches to adaptation and mitigation in Asia and Oceania

Country	Approaches to Adaptation and Mitigation
Armenia	Transformation in population behaviour and government decision-making: (1) mandatory use of air conditioners in offices/workplaces and residential premises; (2) time out/breaks during the hottest day in summers; (3) expanding green spaces in cities; (4) adding more water fountains in cities.
Australia	Australia's Bureau of Meteorology plays a role in disseminating information on forecasting climate-related health events (heat stress and thunderstorm asthma); this is not explicitly linked to a broader national CC&H policy. Overall, very little has changed in Australia's adaptation space since the baseline 2018 report. An update on these indicators was included to highlight that inaction on climate adaptation risks serious damage to infrastructure and people's health and will be increasingly financially costly without leadership in adaptation planning and implementation. Australia has seen slight progress in transitioning to clean technology and shifting towards lower carbon and renewable sources. However, overall, Australia lags well behind other developed countries, particularly in terms of clean energy uptake and coal phase-out. The uptake of sustainable transportation, as measured by the uptake of electric-drive vehicles in Australia, also remains relatively slow compared with international standards. This means that Australians miss out on less-polluting sources of energy production and on the substantial economic benefits associated with a transition to clean technology.
Azerbaijan	Preventive measures focus primarily on the development of technologies that increase the opportunities for sustainable and efficient use of land and water resources, and optimization and adaptation of the agricultural sector. • of drought- and salt-resistant crops created in the field of plant breeding in different soil and climatic zones. Soil monitoring and comparative research to study the consequences of climate change. • Development of mathematical forecasting models based on complex and multidisciplinary research. • Conducting research into maintaining soil fertility, and preventing salinization and water and wind erosion. • Development of an improved agro-technical and phyto-meliorative measures to prevent soil erosion. • Application of water-saving irrigation systems in arid zones; development of the concept of efficient use of existing water resources. • Studying the possibility of adaptation of new varieties

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Table 4.2 **(*continued*)**

Country	Approaches to Adaptation and Mitigation
Bangladesh	The National Action Plan is almost in preparation. The Bangladesh Climate Change Strategy and Action Plan has also been reviewed and reproduced for its next phase and is expected to be published in 1–2 years. The government is also seeking funding from international organizations through the Green Climate Fund. In development planning processes, climate change has also been made imperative for long-term sustainability of those projects' outputs.
China	Continued efforts and positive progress have been made in mitigation of, and adaptation to, the human health impacts of climate change in China in recent years (Cai *et al.* 2018). China has promoted the establishment of health monitoring, investigation, and risk assessment systems, and formulated public health emergency plans and rescue mechanisms for climate-change-induced epidemics such as dengue fever. China has also organized human health protection programmes in the context of adaptation to climate change to improve the public's ability to cope with extreme weather. In addition to national-level actions, pilots have been introduced in various provinces (regions and municipalities) for monitoring health hazard factors in public places, and early-warning systems for high-temperature heatwaves and health risks have been established.
India	The dominant approach for adaptation and mitigation of health impacts of climate change in India is focused on (1) providing enhanced public health care services and (2) assessing the increased burden of diseases due to climate change (Government of India 2008). It is noted that the emphasis on curative measures tends to dominate planning as compared with preventive measures (Ma and Sood 2008). This approach carries the seeds of failure in the face of existing weak supply and delivery systems in many Indian states and the imminent health issues attributed to new vectors arising from the changing climate (Mishra *et al.* 2008). The approach has been criticized for its excessive focus on building infrastructure and resources and less on the adaptive behaviours and responsiveness of people and institutions. Raghunandan (2013) studied India's stand with respect to climate response on the global platform. He found it to be rather reactive with inadequate measures to deal with the climate crisis. The study argues that India could benefit more from a proactive role in global climate negotiations and has a lot of solutions to offer by following the principle of 'common but differentiated responsibilities'. The study finds bottom-up pledges and review systems to be flawed and incapable of delivering the desired results, particularly with reference to restricting a 2 °C rise in temperature.
Indonesia	Many provinces in Indonesia are refining their public transportation. The government is giving subsidies to transportation operators to aid them in improving their services. However, public transport is not yet able to attract many people because of its unreliability and because it is considerably affordable for most people to buy a motorbike by credit payment. There is a growing movement to use zero-emission transport such as bicycles. Some province and district governments facilitate this initiative by providing special lanes for pedestrians and cyclists. In Yogyakarta, a local community scheme called SEGO SEGAWE, which means 'Ride the bike to go to work and to school' has been established. This has been widely accepted by the local people. Apart from reducting GHGs, it has a co-benefit of increasing physical activity among the community.
Japan	Communication across different sectors is essential for effective adaptation and mitigation. Because all sectoral impacts eventually lead to health, health impacts can be made into a common index for multi-sectoral impact assessment and adaptation/mitigation planning. For this purpose, surveillance and monitoring is an important first step for evidence-based policy-making. Good monitoring and surveillance data can be used to plan and prioritize measures to minimize the impacts on health and to identify vulnerable populations. In addition, these data also allow different sectors to evaluate their performance, and improve new and existing ways to minimize health impacts. These approaches should at the same time lead to less GHG emissions. Social transformation is also an important factor to be considered: for example, social transformation in response to the COVID-19 pandemic that has affected the global population. Counteractions against the pandemic, particularly those sharing common goals with climate change adaptation and mitigation actions, could be important key areas that help promote awareness and controls.

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Table 4.2 (*continued*)

Country	Approaches to Adaptation and Mitigation
Malaysia	Various adaptation measures have been adopted by the Ministry of Health to enable health-care facilities to be resilient to floods: (1) infrastructure measures; (2) enhancing or sustaining health services; (3) preparedness and response plans; (4) health personnel capacity building. Site selection for new health-care facilities is based on the Guideline and Regulations for Site Selection and Project Equipment Needs of the Ministry of Economic Affairs. Adequate measures were taken to ensure sustainability of operation during the acute phase of disasters (MESTECC 2018). Guidelines and plans such as the Crisis and Disaster Management Plan for the Ministry of Health 2015, Guidelines on Internal Emergency Preparedness Plan for Ministry of Health Hospitals, and Guidelines on Flood Management for the Ministry of Health have been established. • Upgrade, relocate, or redesign existing health-care facilities that are frequently affected by floods. • Enhance logistic facilities and ensure adequate supplies of food, safe water, medical items, and electricity (using four-wheel-drive ambulances and boats in flood-prone areas). • Upgrade current resources to accommodate the availability of essential utilities and resources for up to 3–5 days in health clinics and 2 weeks in hospitals. • Basic medical treatments as well as prevention of communicable diseases are provided at all relief centres (24 hours). • Establish registries on vulnerable groups and early evacuation plans to safer health-care facilities. • Enhance the capacity building for crisis preparedness and disaster management during floods through technical training of staff by survival training and flood simulation exercises. • Enhancing post-disaster psychosocial support services to minimize the impact of disasters on affected communities and health-care workers.
Nepal	Nepal's GHG emission is low compared with other nations, although it is increasing rapidly. The sectors contributing most to climate change are agriculture and forestry (about 90% of carbon emissions). Mitigation efforts should, therefore, be concentrated in these areas. Proper attention to these sectors will help to build resilience and increase communities' adaptive capacity. Mitigation efforts such as incorporation of proper forest management techniques, promoting alternative energy productions, and modifying agricultural practices can even help generate revenue from carbon trading. Increases in adaptation capacity, revenue generation, and economic empowerment are major co-benefits of mitigation of climate change in Nepal (Maharjan and Joshi 2013).
New Zealand	The 5th Assessment Report of the IPCC concluded that, in the near term, the most effective measures to reduce vulnerability to ill health caused by climate change are programmes that extend and strengthen basic public health functions. This remains true, but adaptive measures are commonly not implemented, even in a high-income country such as New Zealand. In this country, climate change risk assessments have been undertaken by local government, demonstrating marked socio-economic and spatial variations in vulnerability to ill-health caused by extreme weather, but there have been few meaningful interventions. The first national climate change risk assessment was performed in early 2020, and it is intended this will form the basis of a National Adaptation Plan, as required by the Zero Carbon Act of 2019. The release of the risk assessment has been delayed, and it will not be made public until after the September 2020 general election. An inquiry into the outbreak of gastroenteritis in Havelock North recommended that all registered drinking water supplies (which supply about 80% of the national population) in New Zealand should be disinfected, and that stronger oversight must be provided by a national regulatory body. There remains a liability with unregistered supplies, which are typically in remote locations and serve small populations. Partnerships between water and health researchers and local communities have pointed to ways in which local Indigenous knowledge may be applied to protect supplies in these settings. Biosecurity arrangements, particularly applying at airports, harbours, and freight depots to prevent the introduction and spread of vectors of climate-sensitive diseases, are critically important in keeping diseases such as dengue fever out of New Zealand.

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Table 4.2 (*continued*)

Country	Approaches to Adaptation and Mitigation
Pakistan	The National Climate Change Policy of 2012, Framework for Implementation of Climate Change Policy and the Work Program on Climate Change Adaptation and Mitigation (2013) were released to steer cumulative actions towards achieving climate resilience at national and subnational levels. The Ministry of Climate Change is the main institution for climate change in Pakistan. It evolved in 2010 from the Ministry of Environment after the 18th Amendment in the Constitution. The National Disaster Management Authority is another important institution which serves under the Ministry of Climate Change. After identifying the major effects of climate change, adaptation measures have been delineated. These include modernizing irrigation infrastructure to conserve water; construction of additional water storage systems; construction of dykes and sea walls; focusing on renewable energy rather than fossil fuel; and reforestation of catchment areas. Improvements in public health infrastructure, population control, and the involvement of civil society will remain the key elements in implementing the adaptation and mitigation strategies.
Republic of Korea	• Promotion of emergency medical support and infectious disease prevention measures in weather disaster areas. • Establishment of comprehensive measures to minimize damage caused by heatwaves and cold waves. • Strengthening the capacity to promote environmental health measures affected by climate-change-related diseases on a regional basis. • Providing environmental health services to the public in relation to diseases affected by climate change. • Development of co-benefit adaptation measures in the health sector. • Design of a public medical institution 'Green Hospital' and expansion of green areas around the hospital. • Promotion of urban greening and health city projects with local government.
Russian Federation Far East	In recent years, environmental medicine has emerged as a new thread of medical activity, which requires new methods of rapid diagnostics and monitoring the health status of residents of ecologically disadvantaged territories. The issues of rapid diagnostics, the intensity of adaptation processes, and the quantitative assessment of the effectiveness of human adaptation to the environment concern not only medical professionals of various specialties, but also ecologists, geographers, teachers, and psychologists. Studying the specific characteristics of adaptation among residents of ecologically disadvantaged territories is now becoming an important component of environmental monitoring, and typing of adaptive portraits of residents of extreme regions is considered one of the urgent tasks of medical geography and environmental medicine.
Turkey	After the adoption of the National Program and Action Plan on Reducing the Negative Effects of Climate Change on Health, on 21 January 2015, it started to be adapted as follows. • The Ministry of Health organized a workshop on 12 January 2016 and received the opinions of the institutions and academicians on the National Program and Action Plan. • The Ministry of Health organized a second workshop on 5 and 6 April 2016 on the National Program and Action Plan to establish implementation commissions.

4.3 Mitigation and co-benefits

There is a global interest in reducing the emission of short-lived climate pollutants such as carbon black, ozone, and methane. Many initiatives that reduce GHG emissions have benefits that go beyond contributing to climate change mitigation. It is widely appreciated that many mitigation strategies will also have co-benefits on society. Climate change mitigation strategies can have large impacts on air quality, health, and agriculture. Clean air and active lifestyles are the two most obvious health co-benefits.

Some of the mitigation initiatives and strategies are the following:

- increase energy efficiency;
- reduce fossil fuel use in transport and in domestic and energy consumption;
- promote the use of renewable energy sources;
- support low-emission clean transportation;

- use public transportation;
- increase short- and long-term renewable energy targets;
- educate and encourage public participation and acceptance in mitigation strategies.

The following paragraphs describe some of the co-benefits of mitigation.

1. Transportation

In China, electric vehicle car sales reached over 0.8 million in 2017, exceeding 40% of global sales (Watts *et al*. 2018). In New Zealand, it is estimated that a 5% shift from light vehicle kilometres travelled for short journeys to cycling would save about 50,000 tons of carbon dioxide and lead to 5.6 fewer deaths from diseases caused by traffic pollution each year.

Increasing the connectivity and presence of public transport in cities plays an important role in reducing air pollution by reducing private vehicle use. In addition, this also expands job opportunities for poorer people whose movement and opportunities to work and study are otherwise limited to local areas near their homes.

2. Household energy consumption

In 2015, more than 204,000 premature deaths in China were related to coal burning (Watts *et al*. 2018). Study shows that if China achieves its Nationally Determined Contribution, which promised that the carbon dioxide emissions per unit of gross domestic product should fall by 40% compared with 2010 levels, the health co-benefits from carbon emission in electricity generation could offset 18–62% of the cost of emissions in 2030; however, if China does not achieve its Nationally Determined Contribution, the costs of emissions in 2050 will be 3–9 times higher than they otherwise would be (Cai *et al*. 2018).

Reducing the reliance on coal as a primary source of energy in India will lead to a reduction in the nation's GHG emissions but will also reduce the pollution of air by multiple toxic by-products of combustion. The same is true at a household level, when converting cooking from biomass burning to natural gas or electricity reduces GHG emissions, which also has a huge impact on reducing chronic obstructive pulmonary disease in rural women.

3. Healthy lifestyle

Cycling can reduce GHGs while reducing the effects of a sedentary lifestyle. Chronic diseases such as cancer, obesity, type II diabetes, and heart disease are related to physical inactivity. A cross-sectional survey in the northern Chinese city of Jinzhou found that physical inactivity was one of major factors associated with poor health-related quality of life (Dai *et al*. 2015).

About 8,578 deaths in Jiangxi province could be attributable to insufficient physical activity in 2010 (Xu *et al*. 2014). In fact, the health benefits from cycling are much greater than the air pollution savings alone: it was estimated that the increase in physical activity that resulted from moving only 5% of trips to a more active mode would save about 109 deaths each year.

4. Housing

In New Zealand, community trials of improved housing have shown the opportunities for savings in terms of energy use, GHG emissions, and human health. Retrofitting houses with insulation led to greater energy efficiency, reduced power use accounting for about 217 kg of carbon dioxide per household per year, and significant health gains. For those who lived in warmer and drier homes, there were fewer GP visits, fewer hospital admissions for respiratory diseases, fewer days off school for children, and fewer days off work.

5. Dietary and food system

Dietary changes offer opportunities for reductions in both GHG emissions and diet-related ill-health. A New Zealand specific life-cycle assessment investigated the climate, health, and health system cost impacts of shifting from current patterns of consumption to those that would conform with the national dietary guidelines. Such a change would avoid up to 40% of diet-related emissions (depending on the extent of food switching and minimization of waste), improve population health substantially (gaining 1.0–1.5 million quality-adjusted life-years), and save the health-care system as much as EUR8–12 billion.

6. Agriculture and forestry

In Armenia, with proper agro-climatic zoning of the territory of the republic, it has been possible to increase the yield and variety of crops, provide more opportunities for livestock farming, increase the upper borders of forests, and reduce the cost of heating buildings (but increase the cost of air conditioning). In Turkey, owing to the introduction of a feed-in tariff, renewable energy targets (30%) set for 2023 were reached. Turkey has made enormous progress in reducing carbon dioxide emissions while increasing the number of forests. It is important to reduce emissions from agriculture, integrate compliance, and promote low-cost climate-friendly measures (OECD 2019).

7. Technology transfer

The policy about the effect of climate change in Japan involves the transfer of existing Japanese technologies to the other Asian countries in need.

However, the overall effects of co-benefits remain uncertain, warranting more investigation. More research is also needed to elucidate the direct contribution of this strategy on short-lived climate pollutants in reducing heat-related risks. Further examples of mitigation and adaptation are given in the following section.

4.4 Case studies in mitigation: sustainability and health in Asian cities

In cities of Asia and Oceania, mitigation measures are essential for sustainability and the health of citizens. For instance, urban forests are critical in building sustainable cities. Nagpur, one of India's greenest cities with a green space of 31 m^2 per head has relatively better air quality than other cities of its size in India. There is also ample evidence to show that green spaces, even in small residential urban areas, are beneficial for mental health.

The COVID-19 turmoil experienced by many countries drastically reduced carbon dioxide emissions because of the implementation of government policies to decrease industrial activities in many Asian cities and has resulted in cleaner ambient air. To better describe the mitigation and adaptation strategies for sustainability and human health, there are several case studies of Asian cities, as follows.

4.4.1 Klang Valley Mass Rapid Transit System

The transportation sector, particularly road transport, is the second largest carbon emitter in Malaysia (25%) after the energy industry (MESTECC 2018). Motorized transportation has been linked to air pollution, traffic injuries, and sedentary lifestyles that lead to increasing premature morbidity and mortality from chronic non-communicable diseases (Khreis *et al*. 2016; Department of Environment 2018; Schraufnagel *et al*. 2018). The Klang Valley Mass Rapid Transit system (KVMRT)[29] is the largest transport infrastructure project invested by the Malaysian Government. Annual estimations of net carbon dioxide reductions, mortality cases, DALYs, and air pollution using $PM_{2.5}$ as its proxy are shown in Table 4.3.

To achieve the estimated amount of emission reduction and health co-benefits, the daily ridership of the KVMRT needs to reach the projected figures. By August 2019, the ridership of the SBK line had reached 47% of its capacity and was increasing as more development began to build up around the MRT stations (Choong 2019). The potential

[29] The KVMRT system has two lines: the Sungai Buloh–Kajang (SBK) line and the Sungai Buloh–Serdang-Putrajaya (SSP) line. The SBK line consists 31 stations along a 51-km route while the SSP line consists 37 stations along a 52.2-km route.

Table 4.3 Annual estimations of carbon dioxide reductions, mortality cases, annual DALYs, and air pollution from the two KVMRT lines (Sungai Buloh–Kajang (SBK) and Sungai Buloh–Kajang (SSP))

KVMRT line	Net CO_2 reduction (tonnes)	Mortality	DALYs	Air pollution (µg/m^3)
SBK	11,343	–83	4,334	0.056
SSP	31,632	–100	5,253	0.068

for a modal shift depends on the individual trip characteristics (purpose, duration, and distance) as well as the service quality provided (reliability, convenience, and comfort) (Kwan *et al*. 2020).

In conclusion, the KVMRT system is expected to reduce both the carbon emissions from transport and the health burden from air pollution, injuries, and physical inactivity in the city. However, the first and last miles of the MRT system are important to fully leverage the public transport system in mitigating carbon emissions and improving public health.

Figure 4.2 The location of the Caspian Sea.

4.4.2 Prevention of intrusion of the Caspian Sea

The main factors determining the climate of the Caspian Sea[30] – its geographical location, the nature of atmospheric circulation around it, and the impact of surrounding land areas – are the Aral–Caspian lowlands in the east, the Caucasus Mountains in the west, and water exchange between different parts of the sea (Figure 4.2). The main characteristic of the Caspian climate is the predominance of anticyclone weather conditions: sharp temperature changes throughout the year; cold windy winters in the north Caspian; and hot weather in the south Caspian as well as hot, dry, and calm summers throughout the Caspian Sea.

The Caspian Sea is oceanic in origin, with an average salinity of 12.85‰ (per mille[31]) (the average salinity of ocean water is 35‰). The low salinity is because the Caspian Sea is closed and fed mainly by river currents. It has more carbonates and sulfates, and fewer chlorides, than oceanic waters. Wide fluctuations occur, especially during periods of strong north and south winds in autumn and winter.

Observations are made of water level, water temperature, salinity, colour, transparency, wave height, length and period, air temperature, humidity, amount of cloud, wind speed and direction, and atmospheric pressure. Precipitation in the Caspian Sea is also measured by an observation network to study its hydro-meteorological conditions. Studies covering the hydro-meteorological regime of the Caspian Sea are done four times at stations and points located in the coastal zone and open sea.

With continuous information received from the observation network, it is possible to analyse the long-term hydro-meteorological conditions of the Caspian Sea. The Azerbaijan National Hydrometeorology Department exchanges information in cooperation with CASPCOM,

[30] The Caspian Sea is the world's largest inland body of water, variously classed as the world's largest lake or a fully fledged sea.
[31] 'Per mille' is an expression that means parts per thousand. Other recognized spellings include per mil, per mill, permil, permill, or permille. The associated sign is ‰, which looks like a percentage sign (%) with an extra zero in the denominator.

the coordination centre of the Caspian littoral states (Azerbaijan, Iran, Kazakhstan, Russia, and Turkmenistan). Climate change affects all hydro-meteorological parameters as well as the sea level.

4.5 Co-benefits from action on agriculture and food systems

In many developing South Asian countries, for example Nepal, agriculture is responsible for 80% of their GHG emissions. Indiscriminate use of pesticides and fertilizers leads to nitrous oxide in the air and toxic waste in water. Precision nutrient management is used to improve the efficiency of fertilizer use by applying the right form, amount, and time of fertilizer. While this process minimizes nitrous oxide pollution it also increases yield and reduces costs to the farmer, benefiting general rural health.

In India, agriculture, forestry, and related land use account for 24% of global anthropogenic GHG emissions. India has 15 different agro-ecological zones based on climate, soil type, fertility conditions, cropping patterns, and hydrology. Only 35% of the agricultural land is irrigated and two-thirds of it is completely dependent on monsoons. Puddle-transplanted rice cultivation is a significant source of methane emission. Direct seeded rice cultivation is a more sustainable alternative for mitigation although with the associated problems of increased risk of pathogen infections and high weed infestations.

This strategy of rice cultivation also has multiple co-benefits: for example, it is less labour intensive, helps water conservation, reduces the risk of nematode infections for farmers, and reduces mosquito breeding grounds leading to a lowered risk of malaria.

As agricultural practices have changed in the northern part of India, in recent years, burning crop stubble (about 80 tonnes are burned annually) has become a major cause of air pollution in the Gangetic plain. In 2019, farmers in the Karnal district in Haryana moved to manual harvesting instead of mechanical harvesting and stubble burning.

The remaining harvested excess was sold to farmers with livestock, thus bringing in extra revenue to these farmers. The crop waste can also be used in the paper industry and for ethanol production. Air pollution in northern India is positively associated with multiple indicators of health such as morbidity, mortality, respiratory function in women and children, and chronic obstructive pulmonary disease.

Improvements to the air quality will not only improve lung function but reduce many other associated comorbidities. However, these cause–effect relations can be seen only in the long term, and studies into this are urgently needed. Yields of wheat and rice are projected to reduce by 6% and 3.2%, respectively, with each degree (Celsius) increase in temperature.

Coarse grain crops are found to be more climate resilient, but with lower yields. Meat and dairy farming is one of the primary causes of methane and carbon dioxide emissions in countries with large-scale production. Thus, there is a push towards more sustainable vegetarian diets. These changes in our eating habits, for example coarser grains and more vegetarian diets, are also recommended for health reasons. Thus, restructuring of agriculture along these lines will have multiple health co-benefits.

In the field of agriculture in Armenia, various projects are being implemented to combat desertification (such as the use of modern methods of agricultural production), to restore and expand forested areas, and to improve natural pastures and hayfields.

There are strong links between risk management adaptation policies and government responses to protect farmers from the effects of climate change in the Russian Federation Far East. For example, there is support for insurance schemes for ex-post payments as incentives to diversity farm production and practices.

4.5.1 Exploring roles of community forests

Pandey *et al.* (2016) performed a case study of climate change mitigation and adaptation in Nepal, and explored the potential of community forests in addressing climate change issues. The study explored the role of the Reduced Emissions from Deforestation and forest Degradation, conservation of forests, sustainable management of forests and enhancement of carbon stocks in forests (REDD+) pilot programme by analysing data of carbon stocks after the introduction of the programme in 105 existing community forests. Community forests are vital for communities dependent on forests as they allow communities to make concerted decisions in the extraction of resources such as timber and fodder, the sharing of resources, extracting them for income-generating activities, and for food in times of reduced agricultural production.

The REDD+ project was introduced in community forests to increase the biomass and carbon stock in them, by encouraging community members to 'reduce extraction of biomass from forests, control damage due to forest fires, use improved cooking stoves which consume less quantity of firewood than traditional ones and use biogas as a fuel' (Pandey *et al*. 2016). Increased carbon stock and biomass help to mitigate the effects of climate change, increase the availability of these resources during periods of reduced agricultural productivity and during EWEs due to climate change, and increase the adaptation capacity of the communities utilizing community forests. The study posits that its findings are applicable to many developing countries with forested areas under ownership of the community (Pandey *et al.* 2016).

4.5.2 Ethanol production and fuel substitution

Silveira and Khatiwada (2010) explored the potential for development and growth in the industrial sector, specifically in sugar production, by establishing avenues for ethanol production and fuel substitution that could increase economic opportunities for the national economy, and having the potential to mitigate climate change by potentially reducing GHG emissions. The study suggested that '18,945 m^3 ethanol can be annually produced in Nepal without compromising the production of food products from sugarcane'.

This will cut gasoline imports by 14% and save USD10 million annually through the introduction of E20 (a mixture containing 20% ethanol and 80% gasoline) as a transportation fuel. Production of E20 will have several co-benefits such as increased agricultural production of sugarcane as well as environmental benefits such as reducing carbon emissions, consequently mitigating climate change.

4.5.3 Climate-smart villages of Haryana

In India, 18% of the total national GHG emissions occur in the agriculture sector, wherein there is a potential to mitigate 85.5 million tonnes of carbon dioxide per year, nearly 80% of which can be achieved through cost-effective measures (Sapkopta *et al.* 2019). Rain-fed agriculture is both at the source and impact of climate change. The extreme fluctuations in the temperature and rainfall pose serious threats to rain-fed agricultural production and food security, particularly in the Indo-Gangetic plain.

Various mitigation actions in the agriculture sector not only reduce carbon emissions but also induce resilience through adapted food production and security which has direct benefits through reduced malnutrition and related health issues. Some early evidence of successful interventions for reducing GHGs has been noted in climate-smart villages, which is a community-based approach for sustainable agriculture.

Several villages have been selected in the Karnal district of Haryana where farmers, researchers from national and international organizations, local government leaders, policy-makers, planners, and private sector

Table 4.4 The main interventions on a climate-smart village/farm in Haryana, India

CLIMATE-SMART VILLAGE/FARM					
Weather smart	**Water smart**	**Carbon smart**	**Nitrogen smart**	**Energy smart**	**Knowledge smart**
• Seasonal weather forecasts • ICT-based agro-advisories • Index-based insurance • Climate analogues	• Aquifer recharge • Rainwater harvesting • Community management of water • Laser levelling • On-farm water management	• Agroforestry • Conservation tillage • Land use systems • Livestock management	• Site-specific nutrient management • Precision fertilizers • Catch cropping/ legumes	• Biofuels • Fuel-efficient engines • Residue management • Minimum tillage • Solar solutions for agriculture	• Farmer–farmer learning • Farmer networks on adaptation technologies • Seed and fodder banks • Market information • Off-farm risk management — kitchen garden

organizations can work together to identify the site-specific interventions best suited for the village (Jat and Aggarwal 2014). Efforts are made towards integrating climate-smart agriculture with village development plans by using local knowledge and are supported by local institutions (Jat and Aggarwal 2014). In these villages, farmers adopt a variety of climate-smart agricultural practices (Table 4.4) that support food security, climate risk management, adaptation, and mitigation to varying degrees.

Subsequently, farmers have chosen multiple practices such as laser-land levelling and alternate wetting and drying of rice that reduces water use, improves soil health, and enhances economic growth. These farmers receive agriculture-related advisories on their mobile phones from the meteorological department, scientists, and dealers, which helps them to make decisions. After initial success, the government of Haryana also approved 500 climate-smart villages in the state to grow rice and wheat. This has also led the Government of India to expand climate-smart villages across five other states over 237,000 acres of land (CGIAR 2015).

4.6 Case study in adaptation: action to tackle increasing threats of infectious disease

Infectious diseases form a group of health problems that are highly susceptible to the influences of climate change, as described in Figure 4.4. Adaptation to protect the health of human populations from changes in infectious disease epidemiology that are expected to occur as a consequence of climate change involves actions in health systems as well as in other non-health sectors.

The National Centre for Disease Control and Prevention of the Armenian Ministry of Health primarily focuses on monitoring the distribution, and predicting the spread, of major carriers of VBDs.

Japan has suffered fewer large-scale epidemics of VBDs in the past few decades than other countries. However, there were several outbreaks recently such as the transmission of dengue fever within the Tokyo metropolitan area in 2014. It is possible that this kind of outbreak can occur as far north as Tohoku. Preparation for proper VBD control is therefore necessary.

The COVID-19 pandemic is a strong reminder of the need to be prepared for emerging and re-emerging infectious disease, especially since the prevention of communicable diseases after a natural disaster will be more substantial as EWE-related disasters become more common under the changing climate.

In the past decade, outbreaks and epidemics of infectious diseases have caused epidemiological stress in the Russian Federation Far East. The situation, which

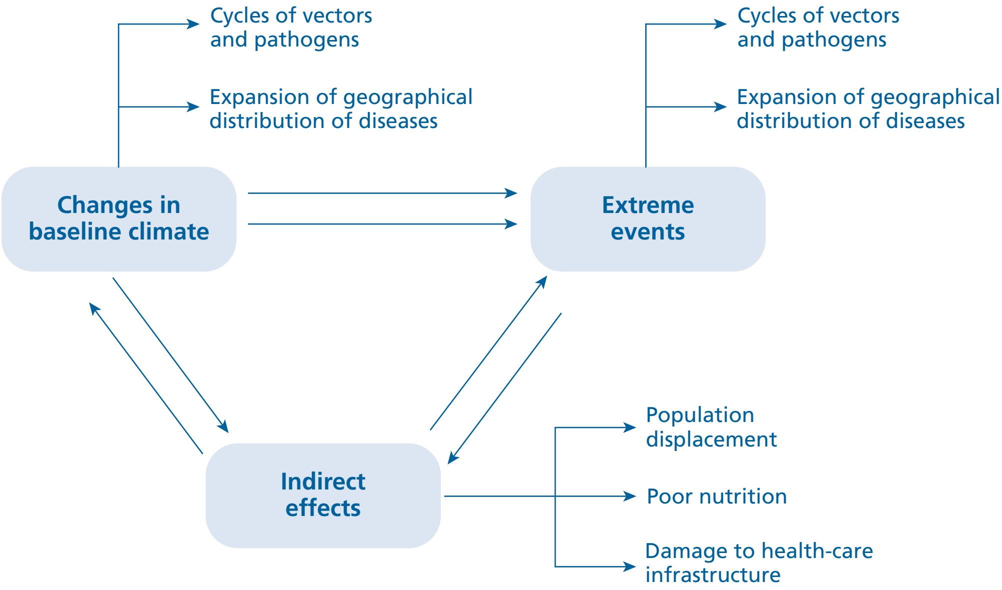

Figure 4.3 Mechanisms of climatic influences on infectious diseases.

Figure 4.4 The 2004 Indian Ocean earthquake and tsunami: one of the deadliest natural catastrophes in history.

causes public health emergencies, can be divided into three groups.

1. Infectious diseases that form an external epidemiological risk and require measures for sanitary protection: smallpox, wild polio virus, human influenza caused by new subtypes, severe acute respiratory syndrome (SARS), cholera, yellow fever, plague, Lassa fever, Marburg virus disease, Crimean haemorrhagic fever, dengue fever, West Nile fever, Rift Valley fever, meningococcal disease.

2. Infectious diseases that form an internal epidemiological risk, requiring registration of single and mass indigenous events, emergency response, and the use of additional forces and means of public health in the region:
   (1) natural focal infectious diseases (plague, Crimean haemorrhagic fever, West Nile fever, rabies);
   (2) common diseases in humans and animals (brucellosis, anthrax);
   (3) the risk of intra-laboratory infection when working with PBA I–IV pathogenicity groups at biologically hazardous facilities.

3. Natural focal infectious diseases of importance in regional pathology, the prevention of which is to implement long-term programmes: tularaemia, leptospirosis, haemorrhagic fever with renal syndrome, tick-borne viral encephalitis, tick-borne borreliosis, tick-borne rickettsiosis, Q fever[32], and others.

Epidemic manifestations of these diseases can lead to emergency situations and require the use of additional forces and means of public health, as well as administrative, legal, and financial support.

4.6.1 Namami Gange Programme: a national mission for a clean Ganga River (India)

The Ganga River is of national importance as the 2,525-km river drains an area of 1,086,000 km^2 across eight states. It acts as a lifeline for millions of people living in rural and urban areas, who use it for domestic, industrial, or religious purposes. Therefore, it has significant public health implications. The excessive human wastes from households, hospitals, factories, and major cities make the Ganga one of the most polluted rivers.

It has been found that 66 out of 97 towns along the Ganga have at least one drain flowing into the river and only 19 towns have their own solid waste treatment plants (Ashok 2019). This means excessive sewage in the river apart from other regular human and animal wastes. The river is filled with virulent bacteria resistant to antibiotics that make it a source of drug-resistant infections that find their way into the human body through sacred water (McNeil Jr 2019).

As a population of nearly 400 million use the water of this river for drinking, domestic purposes, and bathing by ignoring the risks, it poses a significant public health crisis (Pafitis 2017). Owing to significantly high faecal coliform counts in the water, the population is exposed to a variety of diseases such as hepatitis, typhoid, cholera, dysentery, and skin afflictions. The frequency of such disease occurrences can increase in the face of climate change. It is noted that while diseases such as cholera can be treated with proper medicines, certain strains of the disease found previously in the region can cause deaths within a few hours (Pafitis 2017).

The Government of India launched the Namami Gange Program, worth INR200,000 million for 5 years up to 31 December 2020 for pollution abatement, conservation, and rejuvenation of the river and its tributaries (PTI, 21 November 2019). Subsequently, the Government sanctioned 305 projects for cleaning the river. The effects of the project have been noted in the form of improvements in the dissolved oxygen levels at 32 locations, biological oxygen levels at 39 locations, and faecal coliforms at 18 locations in 2019 (PTI, 21 November 2019).

For medical benefits, the government also assured financial support to the Indian Council of Medical Research[33] for comprehensive research (PTI, 16 November 2019). Although some improvement in the water quality has been noted, some experts also have the view that the bacterial count has not yet improved, because of the continuous flow of human waste into the river.

4.6.2 National Dengue Strategic Plan 2009–2020 (Malaysia)

With respect to communicable diseases, Malaysia has taken measures to strengthen its dengue surveillance systems through United in Tackling Epidemic Dengue (UNITEDengue). A structured early-warning and surveillance system for emergency preparedness, called the Dengue Virus Surveillance System, which

[32] Q fever, also called query fever, is an infection caused by the bacterium Coxiella burnetii, commonly found in cattle, sheep, and goats around the world.
[33] The Integrated Conservation Mission, approved as a 'Flagship Programme' in June 2014 to accomplish the twin objectives of effective abatement of pollution, and conservation and rejuvenation of the River Ganga.

consists of real-time smart web-based systems (e-dengue, e-notifikasi, e-vekpro, i-dengue, and a Dengue Outbreak Management System) was established in line with the National Dengue Strategic Plan (2009–2013).

The updated National Dengue Strategic Plan (2015–2020) emphasizes the strategies to strengthen the preparedness and response capacity to detect cases and outbreaks for prompt action. Several early-warning and surveillance systems such as 'e-vekpro' and 'e-notifikasi' have been established for continuous monitoring of malaria and the early detection of outbreaks.

There is concern about the impact of EWEs on food- and water-borne diseases which may become widespread. However, studies of the potential impacts of climate change on the epidemics and endemics of food- and water-borne diseases are still limited (MESTECC 2018).

4.7 Systems thinking for developing coherent strategies: identifying and clarifying synergies, disconnects, and inadvertent consequences

In the SDG process, countries have flexibility in the strategies they implement to meet their SDG targets. This flexibility provides the opportunity to apply planetary health data and integrated tools both to capitalise on multiple benefits among health and non-health sectors and to address trade-offs and unintended consequences of non-health-sector policy decisions. For the SDGs and other global processes, the explicit consideration of multiple benefits and trade-offs for health and natural systems of health and non-health policies should be the strategic objective for producing and applying integrated tools to support the cross-sector engagement and policy coordination needed to protect planetary health.

The need for extensive integration, synergy, and coordination between the multiple arms of government in managing a disaster had never been widely apparent until the COVID-19 pandemic. In preparation for the ongoing climate crisis, public health management systems across nations should work closely with each other and with other governmental departments. Thus, the climate change crisis needs a rethinking of strategies and old wisdom. Modern tools and approaches need to be deployed that can add to the existing processes.

The 2004 Indian Ocean earthquake and tsunami (Figure 4.4) taught us that nature does not recognize national boundaries. Countries in Asia and Oceania have a lot in common in terms of economics and culture. Southeast Asia, especially, shares many weather systems and climatic phenomena. Integration of information systems and data sharing between the countries of this region is critical in our ability to manage the impending climate crisis.

4.7.1 Integration and synergy of development strategies

The complex interactions of climate change and human health also highlight the importance of a systems approach that formulates intervention policies simultaneously and holistically rather than separately. Integration and synergy of development strategies for various sectors of the economy, nature conservation, and development of individual regions and communities are vital for the success of any programme.

For adaptation and mitigation, the health sector alone can achieve little. For example, regulations on where we can build houses make a huge difference to prevent heavy rain-related floods/landslides, rather than establishing a good warning system for extreme rain. Thus, after identifying the important health impacts, communication among the related sectors is imperative.

4.7.2 Avoidance of disconnects and unintended consequences

Effective policies on protecting public health from the adverse impacts of climate change should strategically address upstream drivers rather than the consequences to human health alone. For example, electrified transport could abate exhaust emissions and protect human health locally, but may cause distant emissions with health impacts of different geographical regions if the electricity is generated from fossil sources. Thus, policies to reduce health impacts of transport emissions need to go beyond including the supply chain of electric vehicles.

Systems thinking and approaches that integrally evaluate effectiveness of policies and their systemic impacts could exploit potential co-benefits and reduce policy costs. The health co-benefits of improved air quality have been found to outweigh, or at least counterbalance, the costs of meeting climate policy goals (Markandya *et al*. 2018; Vandyck *et al*. 2018; Cai *et al*. 2018). Integrative and multi-scale policy-making could help to identify which development pathways bring the greatest progress towards air quality, human health, climate, and other goals at the lowest cost.

Nowadays, digitalization is making a valuable contribution in various governmental sectors in countries in Asia and Oceania. Digital health is an emerging and rapidly growing field within the region. An integrated health network can be used for identifying correlations of datasets and emerging patterns of behaviour among the disparate data to establish a deeper understanding of inter-relatedness of events in various spheres of activity in the region. This subject can help develop artificial intelligence (AI)-assisted warning systems which will flag anomalies in patterns and warn of major disasters or health emergencies before they get out of hand.

Systems thinking and its approaches could also facilitate an inclusive, multi-stakeholder process, produce a shared understanding of the system of inter-relationships, feedback, and trade-offs, and support decision-making and governance processes.

4.8 Economic and development consequences

The Asia and Oceania region is uniquely positioned in the global climate change effort. The region contributes over half of the world's total GHG emissions, yet it is also the most vulnerable in the world to the impact of climate change. South and East Asian countries bear the brunt of climate change more than other countries. The effects of climate change, which take place as a result of long processes, appear at the end of many years due to the nature of the climate. Climate change affects the economy and development of affected countries, especially as a result of temperature fluctuations and excessive fluctuations in precipitation.

In 2013, the Russian President declared the development of Siberia and the Far East as the top priority for the country's development in the 21st century. The Russian Government plans to develop measures to make the living standards in the Far East and eastern Siberia attractive to the population. Incomes of residents here should be higher than in other regions, and special tax-free and de-bureaucratic territories should be created for new non-resource industries. The business climate in these zones should also be supported by simplifying connectivity to electricity supplies, obtaining a building permit, and passing customs. Measures to improve public health are also highlighted in the programmes.

Turkey is one of the countries that will suffer the most water stress. This will put at risk of liveability, food systems related to drought, and the availability of natural resources together with agricultural lands (Acar 2020). The yields of products in all regions of Turkey have been estimated to decrease (Dellal *et al*. 2011). Owing to this decrease in yield, it has been determined that production will decrease by 8.18% for wheat, 2.24% for barley, 9.11% for corn, 4.53% for cotton, and 12.89% for sunflower (CSB 2013).

In India, there are multiple studies that have calculated the economic costs of development at regional and global scales. Even though these included mortality and damage to health, they tended to underestimate the true costs because of multiple health challenges, be they linked with diseases or those facing health services (Hutton 2011). The economic and development costs that are overlooked are more apparent at the local level, where various solutions are applied.

India's GHG emissions are currently a third of the global average. This is primarily because nearly 20% of people are poor and do not have access to electricity. The economic and developmental goals of India are to change this scenario and these goals would dramatically increase the GHG emissions. To add to this, modelling studies show that global warming may have amplified the economic inequalities and even reduced India's gross domestic product by nearly 20%.

For growing economies with steep developmental goals, climate change is a challenge and an opportunity. As the world re-orients itself after the COVID-19 pandemic, India is gearing up to move towards more investment in manufacturing, technology, and self-sufficiency. This is an opportunity to draw up new guidelines for industries and enforce previously formulated strategic plans for mitigation and adaptation.

With a global move towards fossil-fuel-free energy, there is an opening to invest heavily in renewable energy and cut coal-based energy production aggressively. Large numbers of businesses have collapsed, and many sectors of the economy suffered heavy losses during the COVID-19 pandemic. This is also an opportunity to ensure that all new industrial and business establishments must not only comply with energy efficiency and non-pollution guidelines but also demonstrate their commitment towards a sustainable future.

The co-benefits of such a committed push towards climate change mitigation and adaption would be employment generation and economic revival, and perhaps a new generation of entrepreneurs with more innovative ideas and commitment towards sustainable development and economic growth.

4.9 Conveying the urgency of the challenges: tackling barriers to implementation

Universal health coverage cannot be achieved without addressing climate change. Health systems planning will need to address climate change now, for many reasons. First, population health is and will increasingly be affected by climate change. Second, health services are affected by climate change when there are climate-related disruptions to communications, transport, and energy networks on which service delivery depends. Third, the health system itself contributes to climate change through energy use for heating, cooling, lighting, and powering equipment. Strengthening health systems to be more climate resilient will involve increasing awareness and building capacity of the health workforce; financing; and integrating health and climate data for monitoring, vulnerability assessment, and early warning.

1. Public sector, private sector, non-governmental organization, and non-profit organization awareness

Educating the public is essential. The public acknowledgement of the impacts of climate change is far from sufficient. For example, in China, natural disasters such as extreme high temperatures, floods, wildfires, and droughts, which have become more frequent in recent years, are related to climate change. But people have not realized the relationship between these disasters and climate change, so they have not paid enough attention to the issue of climate change.

Currently, in Japan, the awareness of adaptation is insufficient. According to a poll by the Cabinet Office, 52% of respondents answered that they did not know about adaptation (Cabinet Office 2016). A-PLAT (the Climate Change Adaptation Information

Platform) has the role of disseminating information on adaptation to the public.

The Japanese Government has been disseminating information related to the impact and measures of climate change to the public. One example is the 'high temperature warning', which warns the public about heatstroke when the maximum temperature is expected to be 35 °C or higher. Another example is 'Health Illness Prevention Information' which provides wet-bulb globe temperature data to warn people about heat-stroke.

Despite having these warning systems in place, the government is still facing issues on how to effectively disseminate information and help the public take action, since the number of fatalities and patients as a result of heat-stroke continues to be high. Efforts are being made to address these issues (Investigative Commission on effective information transmission that contributes to heatstroke prevention measures, 2020).

The awareness of climate change affecting human health is also insufficient in the private sector. Whereas many companies have already formulated business continuity plans to reduce damage disaster on the basis of their past experiences (Cabinet Office 2018a), it is desirable to integrate future climate change and the resulting impact in the plans. At present, however, companies have not been making much progress in adaptation owing to insufficient understanding and the relatively low priority of adaptation compared with other risks. Recently the Ministry of Environment, Japan, published 'the Climate Change Adaptation Guide for Private Companies' (MOE 2019b) to help improve the situation.

The Task Force on Climate-related Financial Disclosures in Japan is one of the mechanisms to encourage companies to disclose climate-related financial information. The Task Force requires companies to conduct scenario analysis to disclose climate-related risks/opportunities and financial implications in order to encourage investors to make appropriate investment decisions.

However, at present, many companies lack the experience and expertise and have only limited human resources for conducting scenario analysis, and it is not easy to disclose information. In addition, how to obtain impact information is also an issue, since the information required depends on each company. To solve these issues, the Ministry of Environment has provided a guide to support companies to conduct scenario analysis (MOE 2020b).

To tackle barriers to implementation, several non-governmental organizations and non-profit organizations have been involved in the activities. For example, the International Council for Local Environmental Initiatives held a seminar and conference to promote adaptations at the local municipality level (ICLEI 2014; 2016). And 'Malaria no more Japan' has been conducting various activities around the world with the goal of eliminating malaria by 2040.

2. Inadequate data and limited access

Lack of detailed data remains a major challenge because of the significant population size of the country. The National Sample Survey covers only a minor population group that may not depict the true picture for detailed planning. Despite several advancements in terms of satellite data collection, limited data are available outside government bodies for research and implementation. Further, in the absence of open data access policies, much of the data collected across different bodies remain unused. Without sufficient data, there are difficulties in developing adaptation programmes to combat the impacts of climate change itself.

In addition, since climate change impacts and their severity may vary from place to place, it is necessary to develop the information on impacts required in each region. Unfortunately, enough information is not always available

(Hijioka *et al*. 2016). In Japan, the National Institute for Environmental Studies established the Centre for Climate Change Adaptation in 2018 in accordance with the Climate Change Adaptation Act to solve these issues. This institute has been conducting various activities to support local authorities in developing local adaptation plans from the perspective of scientific knowledge with the collaboration of relevant government agencies and research organizations.

3. Government support and political interest towards policy-making

Political interest and governmental support for a cause comes from public interest. Thus, it is only public opinion that can create changes in policy. Educating the citizens, especially the younger generation, is the most successful and important way to create a public movement towards climate change. Public movement leads to political will and consequently policy changes.

On the other hand, policy changes mitigating climate change that face resistance from the public need to be addressed by public education. Public disinterest or resistance is only one of the barriers for implementing climate-friendly policy changes.

In a country the size of India, the lack of coordination between arms of the administration is a major barrier when it comes to converting policy to action. Digitization, converting analogue data into digital, as well as digitalization, the use of digital technology and digital data in work, in government would have a big impact on speeding up decision-making, reaching the people at the right time and place and implementing changes.

In India, the most successful efforts at policy implementation have happened when guidance and support are provided to local bodies with a healthy autonomy to choose local solutions suitable for particular situations.

The successful development of the Far Eastern territories on the principles of a green economy and their implementation depends on the active position of state and regional authorities, the development of tax benefits and other preferences for a green business, and, most importantly, on strict control and adoption of effective sanctions provided for by legislation. This requires sufficient economic support for environmental management both at the regional level and at the level of certain types of industry, and strengthening environmental protection. This is one of the main factors in preventing and eliminating the risk of the occurrence and development of environmental problems, ensuring the sustainable development of industrial and natural relations.

4. Insufficient financial and economic support

Some of the mitigation measures need huge economic investment but take effect slowly, which is a great challenge for most local governments. For example, the retirement of old power plants, factories, equipment, and automobiles with high emissions and pollution, and the introduction of new energy technologies, require high and sometimes unaffordable investments for the government, enterprises, and individuals.

In Japan, lack of discretionary budgets and resources for CC&H limits the municipal government effort to implement sufficient adaptation measures. In accordance with the Climate Change Adaptation Act, the establishment of a local climate change adaptation centre and the formulation of a regional climate change adaptation plan are obligations that require action. At present, however, many local authorities are facing issues such as the lack of experience and expertise, and lack of resources for budgetary measures (Hosei University 2015).

5. Limited resource

Despite the best intentions, most plans fail to produce results because of limited resources. For example, public health services in India, particularly in rural areas, suffer significantly for this reason. Although there are provisions for free or low-cost treatment in public hospitals, it is almost impossible to find a bed when they are routinely overburdened. The situation was worst during the COVID-19 pandemic when several people died on the road because of the limited capacity of public health facilities. Meanwhile, there are inadequate sanitary hygiene conditions in several regions in Armenia.

6. Ageing infrastructure and insufficient use due to ongoing focus

Much public health infrastructure in India is ageing and insufficient owing to the continuing focus on COVID-19 and limited human resources. Many hospitals in rural areas lack sufficiently trained medical staff, as doctors and medical staff choose to stay in cities. It causes the limited staff to be busy with existing work, with little scope to plan and engage in new activities.

7. Focus on cities

The emphasis on risk sharing through financial mechanisms such as health insurance is primarily limited to the cities. Government schemes of financial insurance for agriculture and the poor provide limited coverage and bring little relief in emergencies and crisis situations when hospitals are already overburdened with patients.

8. Financial burden on the poor

The proportion of overall spending on medical treatment paid out of the pocket by Asian citizens themselves is high, i.e. 73% in India and 56% in China in 2003 (Ma and Sood 2008). A high financial burden on the poor and sick people tends to enhance the overall vulnerability both to diseases and to delays in treatment.

COVID-19 has exposed the well-needed health infrastructure and services in China. A large-scale migration of the population back to rural areas further suggests that it is now all the more necessary to develop public health systems in the rural and distant areas.

Besides, some of the adaptation measures would bring more GHG emissions and pollutants. For instance, the use of air conditioning is the most common measure to cope with hot weather, but its increasing use may increase carbon emissions if the electricity is generated by fossil power plants and may lead to leaks of fluorine, which is also a type of GHG with huge global potential.

During the fight to combat COVID-19, many countries have been facing the dilemma of whether to pursue a sustainable recovery. China is no exception. If measures in China to respond to the economic fall-out from COVID-19 are aligned with the priorities of the Paris Agreement and the SDGs, transient reductions in air pollution, following the sudden halt in economic activities and road transport, could become more permanent, resulting in further improvements in health and air quality in 2020 and into the future.

However, if the response strategies to COVID-19 implicitly increase the consumption of fossil fuels in China, given the exacerbating effects of future climate change to pollutant accumulation (Yu *et al.* 2019; Horton *et al.* 2014), improvements made in air pollution reduction in China will probably be reversed.

In all, under the backdrop of a complex situation at both international and domestic levels, addressing climate change and protecting human health are facing more unprecedented challenges and barriers than ever.

5 Conclusions and recommendations

The relationship between CC&H is complex, and it is imperative to understand these complexities to formulate policies that can mitigate the direct and indirect effects of climate change. Climate change cannot be denied or brushed aside, because of the mounting scientific evidence and consensus among scientific communities. The impacts of climate change on health will need to be better documented, especially in developing nations where the effects on health will be felt the most owing to the vulnerable population groups in these countries. Quantification of the magnitude and severity of these health impacts is greatly needed.

In terms of climate vulnerability to EWEs, Malaysia is considered to be less vulnerable than other Southeast Asian countries such as Myanmar, the Philippines, and Vietnam. However, climate change will still be a major concern, especially in relation to its impacts on human health. Although heatwaves or heat-related health effects may not currently be an important public health issue in Malaysia, the situation may change in the future. Owing to the increasing proportion of vulnerable people in the population, especially the elderly and those with non-communicable diseases, Malaysia may see more heat-related health issues in the coming years. While significant work has been initiated in looking at future climate change in Malaysia through downscaling of global climate models and future climate predictions by various universities and research institutes, limited research has been conducted on the impacts on human health.

The effect of climate change is also being felt in the vast Indian subcontinent. South Asian countries, India, Nepal, Pakistan, and Bangladesh, are particularly vulnerable to the health consequences of climate change, as discussed in the previous sections, because of their large populations, vast economic differences, rampant illiteracy, and widespread malnutrition. Unhealthy children grow up to become unhealthy adults. Thus, promoting children's health is of paramount importance. Reducing poverty is a key step to be taken by policy-makers to promote the health of future generations in these countries.

5.1 Concerns and challenges in climate change and health

Impacts from climate change are happening now. In certain areas, we have experienced some health impacts of climate change:

- excess mortality due to heat has increased, especially among the elderly;
- heat stress from rising temperatures will increase heat-related excess mortality and morbidity;
- an increase in the frequency of extremely hot days, leading to a higher risk of outdoor heatstroke;
- exposure to night-time heat disrupts sleep, which results in mental and physical stress;
- a rise in temperature and an increase in precipitation during the monsoon;
- changes in the risks and the epidemic patterns of gastroenteritis, water- and food-borne diseases, and certain viral infections;
- shifts and expansion in the geographical distribution of vectors (for example mosquitos) due to higher ambient temperatures have resulted in the widespread incidence of VBDs (for example dengue and malaria) and increased mobility;
- increasing risk of simultaneous disasters, for example sediment disasters, flooding, and storm surges, which have more pronounced impacts than a single event;
- an increasing concentration of ozone, which will increase ozone-related mortality; and
- increasing unreported mental health status among youth and certain groups of people who are seriously affected by climate change.

These impacts are a few among many of the effects of climate change on human health. As millions of people's livelihoods across Asia and Oceania depend on natural resources, the damage caused is enormous. A higher temperature jeopardizes human health.

However, this is an ongoing battle for most of us, but especially developing nations, has to be endured for the time being. At the same time, there are several challenges in climate change that are shared among countries in Asia and Oceania but which vary in their intensity and frequency, as described below.

(1) Despite the dissemination of information on CC&H, there is insufficient awareness that climate change affects human health through various pathways. While direct health impacts, such as mortality from heat and flood, are well recognized, there is a lack of comprehensive understanding about direct and indirect health impacts because of their complex causal pathways (WHO 2003).

(2) Although there has been an increased awareness of the health impacts of climate change, mitigation and adaptation of health systems are planned and executed in a fragmented manner. This needs to be aggressively corrected.

(3) An additional cause for concern is that, unlike most fields of study and areas of influence within a country, the medical community seems to be largely detached from the imminent threat of climate-related health effects. The coming years must see this change, and the medical community must emerge as the leaders in the study, thought, innovation, and influence in decision-making of climate-related health effects and its mitigation as well as in adaptation initiatives and policies.

(4) It is difficult to develop reliable models of the impacts of climate change because of insufficient retrospective climate and health data. This is further complicated by very high microclimatic variations including geographical variations within short distances.

(5) The costs of buying climate and other meteorological data are very high for researchers and governmental bodies. It is, therefore, necessary for international governments to agree to free access of such data for research and surveillance purposes.

(6) There is a shortage of appropriate personnel and human resources for disease surveillance, including environmental scientists, entomologists, environmental health experts, and climate modelling experts. Governments should encourage students to study these fields and show potential for growth, by offering scholarships, learning opportunities, and fellowships.

(7) Some regulations and a lack of clear institutional strategies and mandates make it difficult to establish an integrated disease surveillance and early-warning system. To create a suitable environment for this, it is important to assess the internal and external environments of health systems, focusing on policy implementation and making sure that adequate resources are available (NHRC 2019).

(8) Another challenge is the difficulty in developing a coherent strategy across multiple sectors. The recurrent water-related disasters and earthquakes in Japan, and the COVID-19 pandemic, have urged both the Japanese Government and its academic society to rethink current strategies to prepare for the multifactorial health impacts. The latest Report on Assessment of Impacts of Climate Change in Japan (draft, MOE 2020c) has included 'the impacts of complex disaster' and 'chains of cross-sectional impacts' as new categories of assessment.

(9) A clear gap is noted in the integration of common goals of climate change health

policies at national and state levels. Most health policies at the state level are found to be flawed with vested development interests rather than improving health qualities. There is a need for better integration of policies and planning across different scales and levels.

(10) Compared with the direct impacts, studies of the indirect impacts on health, especially quantitative assessments, have been very limited.

(11) There is also uncertainty in vulnerability. Policy-making should account for vulnerability in the health impacts of climate change. It is well recognized that the elderly are vulnerable to heat stress. Fewer studies have examined the influence of socio-economic status on health effects of climate change even though many are well aware of health disparity.

(12) The biggest challenge for CC&H is implementation. We need to implement the policies already in place to mitigate effects as well as amend and add policies periodically that consider the unpredictable nature of climate change.

(13) In addition to the significant warming observed in the global climate, an increase in global average surface temperatures is expected of between 2 and 4.5 °C in between 1990and 2100, according to the most advanced climate models. Life-threatening changes are expected to occur such as changes in the hydrological cycle, melting of land and sea glaciers, narrowing in glacial areas, rising sea levels, sliding of climate zones, and frequent EWEs.

(14) Climate change also adversely affects many health needs. Among them are fresh air, clean water, adequate nutrition, and healthy shelter requirements. Climate change will negatively affect water quality and accessibility. In some regions, in countries where food is cooked with biomass, nutritional deficiencies can be seen more because of famine and lack of access to healthy water as a result of desertification.

(15) The rising air temperature will directly affect socio-economic (industry and agriculture), ecosystem, and ecological systems as well as human life, particularly in developing countries.

(16) The decrease or disappearance of transportation potential directly and indirectly affects human health.

(17) The impact of climate change on the human immune system has been well documented (undernutrition, psychological stress, and exposure to ultraviolet light). These pathways are likely to weaken the immune system and make populations, especially children, more susceptible to recurring infections, allergies, and development of autoimmune diseases as well as cancer.

5.2 Recommendations according to evidence-based data

Scientific evidence is essential for policy-making to prevent the health impacts of climate change. This report summarizes the health impacts of climate change and the policy suggestions and directions for adaptation and mitigation. The report also clarifies the current research gaps. Scientific knowledge on health risks related to climate change is essential to tackle this global phenomenon and to take urgent action. These actions should also accompany social transformation towards sustainable development.

The following are the recommendations.

1. Education and training

- Comprehensive understanding about the health effects of climate change, both direct and indirect effects, is crucial. This should include quantitative assessments.

- Awareness-raising activities should be implemented at the social and individual levels as well as in various interest groups (non-governmental organizations and non-profit organizations) to prevent and minimize the negative effects of climate change on health.

- Increasing awareness of climate change on human fertility should prompt wider inter-sectoral collaborations for more in-depth knowledge on mitigation and adaptation to such effects.

- Training of human resources for climate change actions should be accelerated. Trained workforce capacity in the field of CC&H should be increased and a common language should be established on health impacts.

2. Research and knowledge implementations

- Currently, there are several platforms across multiple sectors. However, there is always room for improvement in terms of comprehensive health impact assessment spanning different sectors, with the theme of health as a common denominator. Improving the multi-sectorial framework is warranted in every country and regional grouping to prepare a coherent strategy across multiple sectors.

- Effective health risk communication is also an important part of adaptation for climate change.

- Studies should be made on how to reduce the susceptibility of vulnerable groups.

- Databases should be developed to reveal the relationship between CC&H.

- Continuous data collection and monitoring of infrastructure should be strengthened to examine the climate change process more actively and to develop action plans.

- As there are various health effects of climate change, developing specific and systematic surveys and monitoring programmes for heat-related health outcomes are required.

- Meteorological information, warnings and alerts, and information on prevention and adaptations should be provided through cooperation with relevant ministries and agencies in the nations and regions.

- Geographical heterogeneity in health effects should be considered. A country is vulnerable to natural disasters because of its climate and topography. As such, policies for climate change adaptation in that country should consider natural disasters.

- Conduct mapping of vulnerability and health impacts to understand which populations are under the risk of what threat, and implement interventions to safeguard against the acute and chronic effects of climate change on human health. Pay more attention to translating the health impacts to economic costs in the policy-making process.

- Ministries and government departments that are entrusted with the health of their people should mobilize existing infrastructure to identify and implement early-warning components of the effects of climate change on health.

- Technological innovations to counter climate change, alleviate its health risks, and aid in adaptation should be explored. This is best done nationally and regionally by focus group discussions of concerned experts. Cooperation between all parties should be developed and capacity should be increased. Interdisciplinary and cross-sectoral studies should accelerate.

3. Integrated healthcare facilities, services, and implementation

- The health sector should be an active participant in discussions, action planning, and implementation of all actions on climate change issues led by other sectors (for example food systems, air pollution, etc.).

- It is crucial to ensure health is integrated across the climate change spectrum of initiatives and interventions, and to mobilize existing infrastructure to identify and implement early-warning components of the effects of climate change on health.

- Immigrants and asylum-seekers as well as other vulnerable groups, such as the young, women, and the elderly, should be followed up with a good monitoring programme.

- Stress the immediacy of policy implementation by creating a rapid response team that can effectively implement disease monitoring and surveillance, disaster evaluation, response and adaptation, and proper communication of risks and measures to vulnerable populations.

4. Government support in policy development

- Although individual action plays a crucial role for adaptation to climate change, political will by governments is demanded to transform societies. Decision-makers should focus their attention on protecting human health against the high-level impacts of climate change.

- While providing solutions to the negative effects of climate change on health, solutions covering global health risks and all segments of society should also be produced.

- To address policy needs to protect human health, there will be an increased need for new, integrated insights from more disciplines and knowledge fields (Future Earth 2013).

5. Financial aid and adequate resources

- Almost all adaptation and mitigation initiatives and policies have emphasized climate change as a major threat to public health, but very few and limited budgets have been allocated for health sectors.

- Ensure a sustainable and healthy recovery from COVID-19 that reduces carbon emissions and protects human health.

- Investment decisions made after COVID-19 stimulus plans will shape energy systems and the public's health for years to come. Thus, post-pandemic economic recovery plans should prioritize renewable energy expansion and improvements in energy efficiency.

In response to the emerging issues stemming from the impacts of climate change, the academic community has released recommendations and research needs for disaster management, especially in the field of civil engineering. Although there is some evidence about the prediction and economic impacts of these complex disasters, there is scarce evidence on the health impacts caused by the disruption to infrastructure and lifelines after extreme disasters.

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Appendix 1 Working Group

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Appendix 2 After the bushfires: addressing the health impacts

Bushfire expert brief, September 2020

Overview

- Bushfires have adverse effects on people's physical and mental health.
- Individuals are affected by direct exposure to the flames, exposure to extreme heat, prolonged smoke inhalation, contamination of waterways and food, and through trauma from the fires themselves.
- The prolonged and widespread nature of the 2019–2020 bushfires resulted in more people being affected by bushfire-related health issues than previous events.
- Clearer and more consistent public health advice on how individuals and communities identify, manage, and treat health impacts is needed, including targeted information and plans for vulnerable population groups.
- Knowledge gaps need to be addressed if we are to better manage future impacts on human health, particularly in the context of climate change.
- The scale and intensity of the 2019–2020 fire season presents an opportunity to address these knowledge gaps.

After the bushfires: addressing the health impacts

The Australian bushfire season of 2019–2020 had a devastating impact on the environment, economy, and communities, and resulted in significant negative implications for human health and societal well-being (Filkov *et al*. 2020; Yu *et al*. 2020). The extent, duration, and intensity of the 2019–2020 fires affected an extraordinarily high proportion of the population; an estimated 78.6% of Australians were either directly affected, or indirectly through family and friends (Australian Academy of Health and Medical Sciences 2020; Biddle *et al*. 2020).

The scale of the bushfires brought new health challenges, some of which are not yet well understood and some of which may not yet even be evident.

The extent of the fires also highlighted gaps in our knowledge about the health implications that must be addressed.

Owing to the impacts of climate change, Australia is likely to see increasing frequency and severity of fires over the coming decades (Bureau of Meterology and CSIRO 2018). There is a strong need to understand the changing health consequences of bushfire to provide the support services required.

Fire and heat exposure

Bushfires and heat stress pose a severe risk for anyone in proximity to the flames or within range of the radiant heat released. Burns to parts of the body can be life-threatening or lead to lasting disabilities that require long-term medical treatment and support. Heat can also be a severe stressor, causing dizziness, confusion, dehydration, nausea, exhaustion, and heatstroke, which in extreme cases can be fatal (Mathew *et al*. 2017; Cheng *et al*. 2018; Lawton *et al*. 2019).

Those who may be affected include residents, visitors, and emergency personnel: anyone near the fire or in locations experiencing extreme heat from the fire or the weather. Heat stress, induced by weather, has an impact on pregnancies, and is associated with an increase in mortality in elderly populations and long-term neurological effects (Mathew *et al*. 2017; Cheng *et al*. 2018; Lawton *et al*. 2019). The consequences of extreme heat exposure on human health, caused by bushfire, are not yet clear.

Mental health

A range of psychological factors results from the processing of trauma following bushfire events, with people located at or near a bushfire and those further away experiencing mental health issues. Common mental health impacts include anxiety, depression, substance abuse, and post-traumatic stress disorder (PTSD) (Gibbs *et al*. 2016). Some people may also experience heightened suicidal risk, acute stress, or poor sleep quality (Bryant *et al*. 2014; Goldmann and Galea 2014).

Research on disaster survivors has consistently demonstrated that most people recover without professional intervention within several months (Bonanno *et al*. 2010; International Encyclopedia of the Social & Behavioral Sciences 2015). However, although most people eventually recover over time, a sizeable minority experience mental health problems in the months or even years after the initial event. Recovery from bushfires can be a long process: mental health impacts can emerge at any time following the bushfire event and can last for years. One in five individuals affected by the Victorian Black Saturday fires in 2009 still had a psychological disorder 5 years later, which was more likely to be driven by factors such as financial strain and community recovery than by the direct experience of the fires (Gibbs *et al*. 2016; Bryant *et al*. 2014).

And long-term studies of the Ash Wednesday bushfires in South Australia revealed that the mental health impact of the fire could still be detected in the children of affected families 20 years after the event (McFarlane and Van Hooff 2009).

Ongoing post-disaster stressors, such as rebuilding challenges and social and economic disruption, can also contribute to mental health problems (Bryant *et al*. 2018).

Women living in highly affected communities are more likely to experience domestic violence than those living in less-affected communities, and this is linked to financial strain and mental health issues such as PTSD (Molyneaux *et al*. 2020). Aboriginal and Torres Strait Islander peoples are also more likely to have poorer mental health status and other socio-economic vulnerabilities (Williamson *et al*. 2020).

Respiratory health

Exposure to bushfire smoke, which can be many kilometres away from the fire, can cause respiratory complications such as breathing difficulties and coughing. This is caused by exposure to a complex mixture of gases including varying levels of ozone, carbon monoxide, sulfur dioxide, and nitrogen dioxide, as well as particulate matter, interacting with the respiratory tract (Tham *et al*. 2009). These air pollutants can also cause oxidative stress and inflammation of the lungs, which can exacerbate existing respiratory and cardiovascular conditions or increase the risk of new infections (Loxham *et al*. 2019; Wei *et al*. 2019; Vardoulakis *et al*. 2020a; Yang *et al*. 2020).

There are two main categories of particulate matter: PM_{10} and $PM_{2.5}$ PM_{10} particles, which have a diameter of 10 μm or less, are small enough to pass through the nose and enter the lungs, potentially also affecting the heart (NSW Government 2013). Even finer particles with a diameter of 2.5μm or less, $PM_{2.5}$, are small enough to penetrate deeply into the lungs and enter the bloodstream, causing systemic health issues beyond the respiratory system (NSW Government 2013; Xing *et al*. 2016; Vardoulakis *et al*. 2020b).

Exposure to bushfire smoke can increase mortality and hospital admissions. In one study (Arriagada *et al*. 2020), researchers estimated that during the 2019–2020 bushfires, exposure to bushfire smoke in Australia resulted in over 400 deaths, over 1,100 hospitalizations for cardiovascular problems, over 2,000 for respiratory problems, and over 1,300 asthma presentations in emergency departments.

Eye health

Dust, fumes, gases, and fine particles can irritate the eyes. People with pre-existing conditions such as dry eye, eyelid inflammation or allergic conjunctivitis can be particularly sensitive to irritation from smoke, which can sometimes trigger severe symptoms of stinging, grittiness, burning, and itching (Churchill 2018).

Air pollution can also increase the frequency of such conditions: a study from China, for instance, found that individuals with long-term exposure to air pollution are three to four times more likely to experience dry eyes (Yu *et al*. 2019). In another study investigating the long-term impact of particulate matter on eye health, researchers suggest that exposure to higher levels of fine particles may cause conditions such as glaucoma (Chua *et al*. 2019).

Digestive health, food, and water

Bushfires cause loss of vegetation and can alter soil composition and structure (DeBano 1990; Fitzpatrick *et al*. 2014). If heavy rain follows a bushfire, soil erosion due to water runoff can occur. Runoff can carry sediments and pollutants from bushfire locations and contaminate drinking water supplies. This increases the risk of gastroenteritis, the symptoms of which, such as diarrhoea and vomiting, can cause dehydration and weakness in those affected (Tasmanian Government Department of Health 2018). Runoff following high-intensity fires may also include inorganic components such as phosphorus and nitrogen. These compounds can stimulate the growth of blue-green algae that release harmful toxins into drinking water. High-intensity fires may also increase the exposure of trace metals (Canning *et al*. 2020). Burned materials, such as debris, and elevated water turbidity can also hinder water treatment processes (Smith *et al*. 2011).

Smoke and embers can contaminate water in tanks on properties not connected to town water supplies, making the water undrinkable or blocking pumps.

Bushfire can also damage the energy distribution grid, causing a loss of power for refrigeration which increases the risk of salmonella and campylobacter infections and other pathogens from spoiled foods.

Access to emergency services and information

Loss of power and fire or heat damage to telecommunications and internet infrastructure can prevent people calling emergency services in life-threatening or serious health situations. This can also prevent urgent safety alerts being received by those in the path of fires, putting them at increased physical risk.

Health effects of other contaminants

Beyond bushfire smoke, contaminants can arise from the burning of household chemicals and materials such as asbestos and fuel (Environment Protection Authority Victoria 2020; South Australia Environment Protection Authority 2016). When these contaminants enter the bloodstream, whether through the lungs, ingestion, skin, or otherwise, they can cause harm and can potentially endure in the body for long periods (Grant 2010; Rotander *et al*. 2015).

Are there any populations at particular risk?

People who are particularly vulnerable to the health impacts of bushfires and bushfire smoke include those with pre-existing health conditions such as acute or chronic respiratory infections, heart and lung diseases, and asthma. Children, pregnant women, people with a disability, people who are homeless, those with age-related frailty, and Aboriginal and Torres Straits Islands peoples and communities are also more vulnerable to the health impacts of bushfire (Basnayake *et al*. 2017). A recent study reported that over one-quarter of the Indigenous population of New South Wales and Victoria live in areas directly affected by the 2019–20 bushfires (not including bushfire smoke), and that Aboriginal people were among those most affected (Williamson *et al*. 2020).

Women, children, those with greater direct exposure to the fire, and people with low or negative social support and previous mental health conditions are at higher risk of post-disaster mental health problems (Goldmann and Galea 2014).

Pregnant women tend to breathe at a faster rate, which may make them more vulnerable to smoke exposure. Some research has linked extended exposure to fine-particle pollution from fires to unwanted pregnancy outcomes such as pre-term births and lower birthweight (Payam *et al*. 2013; Jedrychowski *et al*. 2017). We also do not know whether fine particles and other toxins are transferable through breast milk to babies, or how heat stress or the stress of an emergency may affect infants.

Children are particularly vulnerable because of their level of activity, the fact that their respiratory system is still developing, and their relatively high air intake compared with their body size (NSW Government 2019).

Emergencies potentially exacerbate health inequalities. Access to services and information, including on the management of pre-existing conditions, may be lacking. For example, authorities may advise people to avoid bushfire smoke by staying indoors and by using air conditioning, or in severe cases, air purifiers and face masks. Still, there are socio-economic factors that make it difficult for financially vulnerable groups to implement these measures. Housing standards may also not provide adequate protection from air pollution.

In addition, people in regional and remote areas already have reduced access to health services compared with those in metropolitan areas, which is exacerbated in times of emergency. We know that the quality of the acute response can influence long-term outcomes.

What should we do now?

Climate models suggest that there will be more bushfires over the coming decades and those fires will be more intense than in the past (Bureau of Meterology and CSIRO 2018). There is a need to prevent or better plan for and manage bushfires where possible, and to better mitigate and manage the health impacts of increased fire risk and provide appropriate information and support for patients, communities and health professionals wherever the location.

It is clear from the 2019–2020 bushfire season that many unknowns remain about how bushfires affect health in the short, medium, and long term. This is especially so when the threat of fire and the required responses are so prolonged. The lack of knowledge makes it difficult to provide accurate health advice which has caused anxiety among affected communities and the wider public.

Building our understanding and evidence base

There is an opportunity to address the knowledge gaps about the impacts of bushfire on human health to assist in the development of clear guidelines and more informative health advice, as well as better delivery of health and support services. Some of these knowledge gaps include the following.

- Mental health impacts, particularly on first responders and vulnerable groups. In the case of first responders, although fire services and other organizations may provide short-term mental health support, resource limitations can sometimes mean that long-term follow-up and support are difficult. Research tracking the long-term mental health outcomes for first responders in Australia is limited. Overseas data suggest that long-term mental health outcomes can be considerable (Giesinger *et al*. 2020). However, appropriate long-term follow-up of Australian first responders is crucial if we are to provide adequate support through the full range of mental health impacts, some of which may not emerge for many years

- Underlying biological mechanisms for how air pollution from bushfire smoke causes respiratory problems and exacerbates existing conditions are poorly understood. It is important to better understand the chemical composition and toxicity of bushfire smoke, and how people can protect themselves

- Health impacts of prolonged exposure to bushfire smoke, fine particulate matter and other contaminants on firefighters, other first responders, vulnerable groups, perinatal and neonatal infants, and the general population.

- Reliable metrics and methods to measure and communicate air quality conditions and the health impacts of bushfire smoke. A system needs to be established, specifically for different exposure and pollutant levels.

Developing appropriate plans and advice

Health advice available to the public about bushfires during the 2019–2020 bushfire season should be improved to increase community readiness for future disaster events. The bushfire season also revealed several areas where planning for a bushfire emergency and response needs to be improved. It is important to provide accurate, nuanced, and consistent health advice.

The following changes are required to improve public advice and planning.

Vulnerable individuals and communities

When planning an emergency response or evacuation for bushfire or smoke haze, specific health and health protection advice must be provided and targeted for these communities. For example, pregnant women, postnatal women, their babies, and the emergency and health services who support them require guidelines on when and how to evacuate and clear policies to help infant feeding; Australia does not have an 'infant and young child feeding in an emergency' (IYCF-E) plan, which aims to ensure that nutritional needs are met (Gribble *et al*. 2019).

Use of, and access to, face masks

The correct fit of a P2 or N95 face mask, which is easily compromised by factors such as facial hair, is an essential component in determining whether they protect the user. Incorrect use of face masks can lead to a false sense of security, meaning the user may be unknowingly exposed to unhealthy levels of air pollution. Respirators are another face cover option for filtering air. However, their relatively higher cost may make them less accessible. If the use of face masks or respirators are part of future mitigation and adaptation strategies, clear advice on correct use is needed, which must be supported by more evidence on the effectiveness of masks and respirators. When children have to spend time outdoors, appropriately sized face masks should be available. Similarly, clear advice on the effectiveness of staying indoors and the use of air conditioning and air filtration systems is also required.

Integrate health and mental health care into disaster planning

The immediate need and cost of health services during a bushfire, and their demand during recovery, must be assessed. The communities impacted most directly are often those in rural or remote areas with limited services. Mechanisms are needed to enable access to medical specialists and mental health professionals, potentially at short notice and using digital technology such as telehealth if appropriate. Support services must be better prepared to deal with co-occurring physical and mental health problems, the complexity of which may require long-term support. Burns in childhood, for instance, can increase the likelihood of being admitted to mental health care later in life by up to five times (Duke *et al*. 2018).

Further research to develop a strong evidence base of the human health consequences of bushfire and subsequent community needs will ultimately enable us to create better plans and health advice that cater to all Australians. Targeted advice and strategies are particularly needed for vulnerable population groups.

Figure A2 Bushfires in 2019–2020.

Importantly, in planning for the future impact of bushfire on human health, plans must consider the broader context of current situations. Bushfires do not occur in isolation to other events, and the collective negative effects of multiple events may be compounding. For example, access to mental health services by individuals affected by bushfire can become further strained owing to the additional pressure of COVID-19.

Preparation of this briefing

This briefing has been informed by contributions from Fellows from the Australian Academy of Science and the Australian Academy of Health and Medical Sciences, and other experts in fields including environmental health, respiratory health, mental health, maternal and child health, burns, Indigenous health, public health, and eye health, including through an Australian Academy of Health and Medical Sciences expert roundtable on 13 February 2020. We are grateful for their valuable contributions. To read a full report of this roundtable, visit https://aahms.org/wp-content/uploads/2020/04/The-Australian-Bushfires-and-the-im-pact-on-health_evidence-doc.pdf.

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Appendix 3 Scope of climate change impacts for human health

Some previous reviews of evidence: floods in Kelantan, Malaysia, In December 2014

The December 2014 flood in northeast Peninsular Malaysia was an extreme weather event probably associated with recent climate change around 2009–2010 due to the La Niña phenomenon and subsequent heavy rainfall during the monsoon. The flood left a significant amount of waste that was not cleared, causing water pollution. People were left with poor water, sanitation, and hygiene from a lack of clean drinking water, damaged toilets, and unsafe hygiene practices. This has resulted in significant communicable diseases in the form of rodent-transmitted diseases, vector-borne diseases, and diarrhoeal diseases. The most commonly observed diseases after the December 2014 flood were as follows.

1. Leptospirosis

Leptospirosis is the most common form of rodent-transmitted disease after floods. The disease is typically transmitted through exposure to water contaminated with urine from carrier animals including cattle, pigs, dogs, and rodents, especially rats. Malaysia is considered a country with a moderately high incidence rate (1–10 per 100,000 population) of leptospirosis. During rainy seasons or floods, epidemics may occur with reported incidences above 100 per 100,000 of population.

An observational ecological study using a geographic information system (GIS), spatial–temporal distribution, as well as clustering and vulnerability analysis of leptospirosis in Kelantan was performed after the December 2014 flood (Mohd Radi *et al*. 2018). In this study, led by Jamal Hisham Hashim of the United Nations University, it was found that the incidence had doubled during the post-flood period, with 12 of 66 sub-districts recording incidence rates above 100 per 100,000 of population compared with only 4 sub-districts pre-flood (Yusop and Mahpof 2014a; Mohd Radi *et al.* 2018).

It is possible that displacement of the population to relocation centres could explain higher incidences in certain sub-districts. Clustering analysis using the average nearest neighbourhood indicated that infected cases were more clustered, with an observed mean distance of 1,139 metres post-flood compared with 1,666 metres pre-flood, indicating that peri-domiciliary transmission might play a role.

In addition, vulnerability analysis using geographic weighted regression showed that living close to water bodies significantly increased the risk of contracting the disease. The study also found that disease hotspots were areas where garbage clean-up commonly occurred, and these areas provide a favourable environment that supports the growth of rodents.

2. Dengue fever

Classically an urban disease, dengue has recently migrated into suburban and rural areas. It is a common vector-borne disease that has been associated with floods. Although endemic in Malaysia since 1970, outbreaks have been increasingly frequent and of greater magnitude in recent years, especially 2014-2015. The incidence rate has increased 10-fold from 32 cases per 100,000 of population in 2000 to 361 cases per 100,000 in 2014 (Mudin 2015). At the end of August 2014, 65,000 people (14.5% from Kelantan) were afflicted by dengue fever and 128 were reported dead in Malaysia (Alwi *et al.* 2014).

Around the same period, the world was threatened by the outbreak of Ebola virus. It is interesting to speculate that both these outbreaks were related to the adverse climate change that has been taking place globally since 2010.

It is believed that still water that persists after floods is a breeding ground for *Aedes* mosquitoes. In a systematic review of climate change and dengue in Malaysia, with limited literature, climatic factors including temperature, rainfall, and humidity have been found to be associated with dengue, but the relationships are not consistent (Hii *et al*. 2016). The lag period between rainfall or temperature change and the outbreak of dengue ranges from 7 to 51 days, providing a window or lead time for mitigation control.

From the same ecology GIS study (Mohd Radi *et al*. 2018), they found that during three different periods (before, during, and after floods), dengue showed the highest incidence during the pre-flood period but somehow reduced during and after flood periods, in contrast to what was observed with leptospirosis (Yusop and Mahpof 2014b). However, the reason for this observation was not described in the report.

In a separate 2014 flood study comparing a flooded area (Pasir Pekan) with a non-flooded area (Kubang Kerian), *Aedes* mosquitoes were more abundant and the Ovitrap Index was higher than average in the flooded area, indicating the possibility of higher human transmission (Yusop and Mahpof 2014a). However, there was no correlation between mosquito density and meteorological variables including rainfall, temperature, and humidity. There was also the absence of dengue virus in collected mosquito samples using the NS1 rapid test and RT–PCR (polymerase chain reaction with reverse transcription).

It has been concluded that the occurrence of dengue in Kelantan after the flood might have been due to human movements from the endemic area or human-associated activities including changes in the housing landscape or vegetation.

3. Diarrhoeal diseases

After the December 2014 flood, on the basis of an unpublished survey, the prevalence of acute infectious diarrhoea or acute gastroenteritis in the community was approximately 30% (Yusof *et al.* 2017). Poor water, sanitation, and hygiene is a critical reason for occurrence of acute gastroenteritis after flooding, which can last for months because of poor mitigation in water quality and sewerage management. As a result, microbiological contamination of clean drinking sources might have occurred.

This has been studied by the team from Universiti Sains Malaysia using the metagenomic sequencing approach. In their report, compared with non-flood water samples, the flood water contained more pathogenic Gram-negative organisms, especially *Pseudomonas* species and *Escherichia coli*. Furthermore, *Bacillus cereus* was four times more common in flood water than non-flood water (Yusop and Mahpof 2014b). These pathogens could have been responsible for the high prevalence of acute gastroenteritis that was had observed after flood.

In a separate study from the Universiti Malaysia Kelantan, three water samples were collected from three different locations along the Kelantan River (Sungai Kelantan) 5 months after the floods and examined for microbiological composition using metagenomic sequencing. In the report, pathogenic microbes including *Enterobacter* and coliforms were surprisingly absent, but non-pathogenic freshwater clusters predominated including *Prosthecobacter* (typically found in water with high metal concentrations) at 3% (Yusop and Mahpof 2014b). On the basis of the study, it seems that contamination of the drinking water was unlikely, but it must be emphasized that water samples were only collected 5 months after the floods.

A team from International Islamic University of Malaysia sampled water from submerged wells along the Sungai Kelantan basin and examined its microbiological and physico-chemical properties. Results confirmed the presence of coliforms in 95% of the samples, but coliforms were also present in non-submerged wells, indicating that pre-flood contamination had already existed, again confirming that river water was not responsible for the contamination.

On the basis of the observations described above, two possible causes may explain acute gastroenteritis observed after floods: higher dependence on pre-flood contaminated water sources such as the drinking wells, or contamination of drinking sources by flood wastes or broken sanitation facilities.

4. Post-infectious irritable bowel syndrome

Irritable bowel syndrome (IBS) is a disorder of the gut and brain interactions characterized by chronic abdominal pain and altered bowel habits but without obvious organic cause. Post-infectious IBS, as its name suggests, is a form of IBS of diarrhoeal subtype that has an acute onset following an episode of acute gastroenteritis (Lee *et al.* 2017). From the review of existing literature, the prevalence of post-infectious IBS ranges from 4% to 32%, and bacteria are the most commonly implicated causative agent.

About 6 months after the December 2014 flood, a survey was conducted and stool samples collected from two villages most affected by the flood, about 25 kilometres from Kota Bharu (Yusof *et al.* 2017). From 211 flood victims, there was a 17% prevalence of post-infectious IBS, with diarrhoeal or mixed-type IBS being the most common. Poor water, sanitation, and hygiene practices and impaired quality of life were significantly associated with a diagnosis of IBS. Most interestingly, gut dysbiosis (microbial imbalance in the gut), as determined by metagenomic sequencing and analysed using principal component analysis, was observed especially in flood victims with anxiety.

The most abundant microbiota associated with IBS were *Plesiomonas* and *Trabulsiella* (effect size 3.0). Both *Plesiomonas* and *Trabulsiella* are environmentally derived organisms, and these microbes might have got into the gut of flood victims from contaminated drinking water. Subsequently, these pathobionts then expanded in the new gut environment, and caused the post-infectious IBS.

An intervention with a probiotic (*Bifidobacterium infantis* M-63, Morinaga Milk Industry Co. Ltd, Japan) in the affected flood victims with IBS was conducted to determine whether the probiotic could improve symptoms, their quality of life, and whether the dysbiosis could be reversed (Ma *et al.* 2019). After taking the probiotic for 3 months, the flood victims with IBS reported better mental health and lower bodily pain, and the improvement was related to restoration of their microbial balance.

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