WATER-RELATED DISASTERS AND DISASTER RISK MANAGEMENT IN THE PEOPLE'S REPUBLIC OF CHINA

ASIAN DEVELOPMENT BANK

ADB

WATER-RELATED DISASTERS AND DISASTER RISK MANAGEMENT IN THE PEOPLE'S REPUBLIC OF CHINA

ASIAN DEVELOPMENT BANK

ADB

6 ADB Avenue, Mandaluyong City, 1550 Metro Manila, Philippines
Tel +63 2 632 4444; Fax +63 2 636 2444
www.adb.org; openaccess.adb.org

Some rights reserved. Published in 2015.
Printed in the Philippines.

ISBN 978-92-9257-149-8 (Print), 978-92-9257-150-4 (e-ISBN)
Publication Stock No. RPT157747

Cataloging-In-Publication Data

Asian Development Bank.
Water-related disasters and disaster risk management in the People's Republic of China
Mandaluyong City, Philippines: Asian Development Bank, 2015.

1. water-related disasters. 2. disaster risk management. 3. climate change. I. Asian Development Bank.

In this publication, "$" refers to US dollars.
ADB recognizes "China" as the People's Republic of China.

CONTENTS

Tables and Figures

Tables

Figures

Notes on map data sources:

1. The data for the maps in this review, except for administrative boundaries and population density, were obtained from the Global Risk Data Platform (GRID) website on 21 January 2014. "The United Nations grants permission to Users to visit the GRID Site and to download and copy the information, documents, and materials. All datasets on PREVIEW can be available for free for non-commercial purpose (governments, international organizations, universities, non-governmental organizations, civil society on an 'as is' basis, without warranty of any kind, either express or implied, including, without limitation, warranties of merchantability, fitness for a particular purpose and non-infringement. The United Nations specifically does not make any warranties or representations as to the accuracy or completeness of any such Materials." http://preview.grid.unep.ch/index.php?preview=about&cat=2&lang=eng

2. The data for the administrative boundaries shown were obtained from Global Administrative Boundaries Version 2.0 on 19 January 2014. http://www.gadm.org/

3. The population density data were obtained from the Center for International Earth Science Information Network (CIESIN), Columbia University; and the Centro Internacional de Agricultura Tropical (CIAT). 2005. Gridded Population of the World, Version 3 (GPWv3): Population Density Grid, Future Estimates. Palisades, New York: NASA Socioeconomic Data and Applications Center (SEDAC) on 7 March 2014. http://sedac.ciesin.columbia.edu/data/set/gpw-v3-population-density-future-estimates

Foreword

The frequency and magnitude of natural disasters are increasing in most regions across the world with water-related disasters being the most common and recurrent. The economic cost and toll of these disasters are enormous and are significant obstacles to eradicating poverty and achieving human security and sustainable socioeconomic development. As climate change increases the frequency and intensity of extreme weather, water-related disasters such as floods, droughts, landslides, waves, and surges will pose an ever-increasing threat to vulnerable communities and to sustainable development.

The Asian Development Bank (ADB) recognizes the challenge that natural hazards pose to development in Asia and the Pacific. As part of The Operational Plan for Integrated Disaster Risk Management, 2014–2020, ADB seeks to promote an integrated disaster risk management (IDRM) approach to strengthen disaster resilience and enhance residual risk management through a coordinated and systematic approach to IDRM. To achieve this, ADB supports IDRM capabilities, knowledge, and resources to reduce disaster risk and to respond to disaster events in a timely and cost-efficient manner.

This support for and investment in disaster resilience can reduce losses and contribute to sustained economic growth, continuous poverty reduction, and enhanced natural resources management. When coupled with the context of wider development and with careful integration into the development process, these investments can have a far-reaching effect. With this in mind, this knowledge product aims to inform ADB in its planning for policy and institutional support to the Government of the People's Republic of China (PRC) for water resources development and management. The study presents an overview of water-related disasters in the PRC and their management. Putting water-related disasters in the context of climate change predictions, the report considers impacts, current management and policies to reduce risk, and opportunities for strengthening IDRM. The review will also be of interest to staff of PRC's government agencies, the private sector, other donors and nongovernment organizations to raise awareness about and strengthen capacity to manage risks of water-related disasters in the PRC. Successful investment in resilience also requires active cooperation between governments, the private sector, civil society, and the international community.

Water-related disaster risk management is a challenging topic given the uncertainty and variability in events and multisector nature of the work. ADB is committed to support the PRC to overcome such challenges, address the gaps, build resilience, and learn lessons which may then be shared with other member countries for their awareness and action.

Ayumi Konishi
Director General
East Asia Department

Acknowledgment

This report was prepared by Hugh Milner, consultant, ADB, and Carey Yeager, climate change specialist from the Environment, Natural Resources and Agriculture Division of ADB's East Asia Department. With additional inputs provided by Yuhong Li, Department of Water Resources, Government of the People's Republic of China and Suzanne Robertson, natural resources and agriculture specialist from the Environment, Natural Resources and Agriculture Division of ADB's East Asia Department.

Abbreviations

A1B	an emission scenario for climate modeling, also A1, A2, B1, etc.
ADB	Asian Development Bank
CMIP3	Coupled Model Intercomparison Project Phase 3
CNY	yuan
CRED	Centre for Research on the Epidemiology of Disasters
DALY	disability-adjusted life year
DRM	disaster risk management
EM-DAT	Emergency Events Database, maintained by the CRED, Belgium
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
GDP	gross domestic product
GRID	Global Risk Data Platform
ICZM	integrated coastal zone management
IPCC	UN Intergovernmental Panel on Climate Change
IRBM	integrated river basin management
IWRM	integrated water resources management
MOA	Ministry of Agriculture
MWR	Ministry of Water Resources
NGO	nongovernment organization
PES	payment for environmental services, also known as payment for ecosystem services
PRC	People's Republic of China
RBC	River Basin Commission
SLR	sea-level rise
US	United States
WRD	water-related disaster

Measurement Units

ha	hectare
km^2	square kilometer
m	meter
mm	millimeter
m^3	cubic meter
ton	metric ton or 1,000 kilograms

Note

$1.00 = CNY6.21 (as of 30 June 2015)

Executive Summary

The People's Republic of China (PRC) has approximately 20% of the world's population, but only 7% of the world's water resources. The PRC's rapid economic growth and growing population increased its demand for water, food, and energy, thereby laying stress on its freshwater resources. In 2013, natural disasters cost the PRC approximately $67.95 billion—0.7% of its gross domestic product, almost twice the cost in 2012. This review focuses on water-related disasters (WRDs), including impacts, current management and policies to reduce risk, and opportunities for strengthening integrated disaster risk management (DRM).

There are three primary WRD hazards (floods, droughts, and extreme storms) which may lead to WRDs when there are people or economic goods exposed to such hazards and where there is insufficient preparedness. Floods affect the greatest number annually—approximately 77 million individuals. In terms of economic damage, floods also result in the highest annual damage of about $9.25 billion. Secondary WRD hazards include landslides, subsidence, wildfires, and saltwater intrusion.

WRDs in the PRC are closely related to climate change and environmental degradation. Temperatures are projected to continue increasing, with increased water stress and droughts in some areas. Increases in flooding are also projected, particularly in urban coastal areas. There are measurable implications for human health (from increases in waterborne diseases), fisheries, and agricultural production, and for potential food security.

The PRC has made significant progress in clarifying its medium- and long-term strategic goals under the Hyogo Framework for Action 2005–2015. It is making efforts to recognize current and future risk, reduce and manage those risks, and be better able to adapt to change and recover from disasters.

International experience has provided a number of lessons. At the heart of water-related DRM of any country is the issue of water security. International experience shows that water security can and must be addressed on a river basin basis through a strong and properly enforced water regulatory system, combined with a strategic water resource plan. A key issue in successful implementation is clarity of responsibility for a single and accountable lead organization, such as found in the role of the European Union (EU)— a "Competent Authority" to deliver EU Directives and to ensure accountability and delivery.

The Asian Development Bank's flood and drought studies strongly recommend a risk management approach to disaster management. Risk management is a proactive approach and is focused on the design of measures in advance of a WRD to help prevent or mitigate risk exposure and vulnerability.

Some specific best practices include (i) promoting risk reduction, (ii) providing incentives (payment for environmental services or eco-compensation mechanisms), (iii) establishing links with climate change adaptation, (iv) strengthening linkages between WRD management and integrated water resources management, (v) increasing participatory management, (vi) increasing access to disaster insurance, and (vii) loss estimation.

Water-related DRM presents a challenge for PRC institutions given the multisector nature of the work. Based on this review, there are six main areas wherein multilateral financing may assist the PRC in strengthening its current management of WRDs. These include (i) data management, (ii) monitoring and forecasting, (iii) drought risk management, (iv) flood risk management, (v) sustainable urban development, and (vi) coastal management. A detailed assessment of infrastructure needs would also be highly beneficial, as there are clearly many opportunities.

The preparation of the upcoming Thirteenth Five-Year Plan presents the PRC with an opportunity to address policy gaps, strengthen institutional coordination, and implement new activities to prevent WRDs and reduce its impact through DRM. The PRC may wish to consider the following:

(i) consolidate disaster management legislation, and integrate with natural resource planning and management legislation;
(ii) improve coordination and cooperation; clarify roles and responsibilities between departments, agencies, ministries, and levels of government; and designate a single and accountable lead organization;
(iii) address identified knowledge gaps; and clarify linkages between flood management, river basin management, coastal zone management, and WRD (including climate change impacts);
(iv) scale up eco-compensation programs for watersheds, and broaden the participation of commercial entities and communities;
(v) improve calculations of water availability and demand; and specify water use rights, and regulations for water sharing, trading, and pricing;
(vi) adopt a risk management approach to disaster management;
(vii) improve loss estimations; and
(viii) promote disaster insurance, provide incentives for purchasing, and expand access.

CHAPTER 1

Introduction

The People's Republic of China (PRC) has approximately 20% of the world's population, but only 7% of its water resources.[1] The PRC's rapid economic growth and rising population are increasing demand for water, food, and energy; and stressing its freshwater resources. Natural disasters have cost the PRC approximately $67.95 billion—0.7% of its gross domestic product (GDP) in 2013—almost twice the cost in 2012.[2] Many of these disasters were water-related. Floods, droughts, and severe storms regularly put its population at risk. This review focuses on water-related disasters (WRDs), including identification of underlying causes, current management and policies to reduce risk, and opportunities for strengthening integrated disaster risk management (DRM).

A. Population at Risk

The PRC population of approximately 1.35 billion is increasing at a rate of 0.5% as of December 2012, and is forecast to reach 1.38 billion by 2030.[3] In 2012, 53% of the population lived in cities; and the urban population was estimated to expand at a rate of 2.9% between 2010 and 2015 due to planned in-migration. Expansion of urban populations is fastest in the existing major cities. Average incomes are expected to continue to rise (GDP per capita was $6,207 at current market price in 2012); and if accompanied by increased material holdings, may result in greater potential disaster losses for individual families.

The PRC is concerned about the rapid increase of population in major coastal cities. It is assumed that increased exposure to the economic and social impacts of WRDs would require a major strengthening of water-related DRM. Integration of urban and rural development could assist in limiting increased WRD losses, if new urban development avoids hazardous areas such as those subject to flooding or landslides.

---

1 http://www.economist.com/news/leaders/21587789-desperate-measures

2 British Embassy. 2014. *China in Numbers.* United Kingdom. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/320305/Chinanumbers_-_June_2014.pdf. The cost quoted here is converted to US dollars from CNY421 billion.

3 Information on population is from the Asian Development Bank. *Key Indicators.* http://www.adb.org/sites/default/files/ki/ 2013/pdf/PRC.pdf; and the World Population Statistics for Forecast (2013, 2030). http://www.worldpopulationstatistics.com/china-population-2013/

B. Water Resources

The water resources of the PRC total 2,841 billion cubic meters (m^3); surface water resources provide 2,739 billion m^3 of this total; and groundwater 822 billion m^3 of which 719 billion m^3 is counted both as surface water and also as groundwater.[4] Based on the current population size of the PRC, this amount of water could provide up to 2,200 m^3 per person annually, if completely captured and used solely for anthropogenic purposes.

Water resources are unevenly distributed, with 81% located in the southern part of the PRC (36% of the PRC's total area) and only 19% located in northern PRC. About 10% of the water resources originate in the plains and 90% in mountainous areas. The rivers of the northern PRC (the Hai, Liao, and Yellow rivers) are more variable than those of the southern PRC, particularly than the Pearl and Yangtze rivers. Floodwaters amount to 40% of the resources; and environmental flow requires 32%, leaving only 28% of the runoff available for use.

The amount of water available for actual human use (a total of 795 billion m^3) varies between river basins depending on the degree of regulation available. The range in available water, as a percentage of the total resources, is from 64% (Hai River) to 17% (rivers in the south-west). This measure reflects the variability of surface water flow and the ability to regulate that flow by means of dams, weirs, and reservoirs, and to access groundwater.

Total human water use in the PRC is 590 billion m^3—81.0% from surface water, 18.4% from groundwater, and 0.5% from other sources (e.g., rain collection)—and is continuing to rise. Domestic and industrial water use and wastewater discharge have been growing at about 4% per year over the past 30 years. Domestic and industrial use now total 123 billion m^3, while wastewater discharge is 80 billion m^3. Irrigation water use is also continuing to rise, but at a lower rate.

The northern rivers are under the greatest stress of commitment, and there are no further supply development options within these basins. The current water management strategy in the face of these pressures is to divert water from south to north, improve efficiency of water use, control water demand and pollution loadings, restore the water environment, and ensure water security.[5]

---

[4] Information on water resources and use is from J. Xie et al. 2013. *Addressing China's Water Scarcity, Recommendations for Selected Water Resource Management Issues.* Table 2.1. World Bank. http://elibrary.worldbank.org/doi/abs/10.1596/978-0-8213-7645-4

[5] L. Yuanyuan. 2013. *Long-term Strategy for Water Resources Management in the PRC.* GIWP, Ministry of Water Resources, PRC.

CHAPTER 2

Water-Related Disasters in the People's Republic of China

WRDs in the PRC are closely connected with climate change and environmental degradation.[6] Many types of WRDs increase with changes in temperature, precipitation, and other climate variables. The loss of vegetation cover increases the risk of landslides and also increases the probability of downstream flood disasters.[7] A water-related risk exists wherever people, or private and/or public property, and infrastructure are vulnerable or potentially exposed to harm or damage because of water-related hazard.[8] This review is limited to water-related hazards with a high potential for harm, large damages, or losses exceeding local capacity to adequately respond.

Larger populations and greater levels of development increase exposure in hazardous areas. Planning which has taken into account hazards may discourage or prohibit development, or only permit development (such as recreation areas) in areas with low vulnerability, to reduce exposure. Floodplain planning is an example of reducing exposure to WRD.

The lack of resources, preparedness, or ability, and the location of residences and assets make individuals and communities vulnerable. Vulnerability, however, may be reduced through (i) awareness-raising, (ii) training and organization, (iii) forecasting, (iv) mapping, (v) development controls and early warning, and (vi) access to capital and other resources to build local capacity. A community prepared to cope with disaster, with lower levels of vulnerability, is more resilient to water-related risk.

A. Primary Water-Related Disaster Hazards

There are three primary hazards—floods, droughts, and extreme storms—which may lead to WRDs when there are people or economic goods exposed to the hazard, and when there is insufficient preparedness. This review deals with hydro-climatic causes that include

---

6 L.J. Henderson. 2004. Emergency and Disaster: Pervasive Risk and Public Bureaucracy in Developing Nations. *Public Organization Review*. 4 (2). pp. 103–119.

7 C. Liua et al. 2012. Susceptibility Evaluation and Mapping of China's Landslide Disaster Based on Multi-Temporal Ground and Remote Sensing Satellite Data. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*. XXXIX-B8. XXII ISPRS Congress, 25 August–1 September 2012. Melbourne, Australia.

8 Hazard is defined as "A potentially damaging physical event, phenomenon or human activity that may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation. Hazards can include latent conditions that may represent future threats and can have different origins: natural (geological, hydrometeorological and biological) or induced by human processes (environmental degradation and technological hazards)." United Nations International Strategy for Disaster Reduction (UNISDR). Geneva. 2004. Vulnerability is defined as "The conditions determined by physical, social, economic, and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards." UNISDR. Geneva. 2004.

climate change, temperature, and precipitation extremes. The impacts of these hazards are summarized in Table 1.

Table 1: Average Annual Impact of Water-Related Natural Disasters in the People's Republic of China, 1985–2013

Type of Disaster	Disaster Subtype	Number of Events	Annual Frequency of Occurrence	Annual Number of Deaths	Annual Number Affected	Annual Cost of Damages ($ million)
Drought	Drought	29	1.00	121.86	21,636,417	3,050.25
Flood	Flash flood	19	0.66	56.97	3,855,206	267.61
	General river flood	152	5.24	832.41	66,391,088	8,303.41
	Storm surge or coastal flood	5	0.17	13.48	86,208	No data
	Unspecified	26	0.90	222.96	6,684,669	679.76
Mass movement – wet	Avalanche	2	0.07	2.34	38	No data
	Landslide	54	1.86	158.93	160,506	689.11
	Subsidence					Not recorded
Storm	Tropical cyclone	116	4.00	291.38	11,262,758	2,006.90
	Extra-tropical cyclone (winter storm)					Not recorded
	Local or convective storm	62	2.14	48.48	7,500,300	279.26
	Unspecified	36	1.24	65.62	1,094,360	92.62

EM-DAT = data from the international disaster database maintained by the Centre for Research on the Epidemiology of Disasters (CRED) of Belgium called "Emergency Events Database."

[a] EM-DAT: The Office of Foreign Disaster Assistance (OFDA) of the United States Agency for International Development (USAID)/CRED International Disaster Database. http://www.emdat.be – Université Catholique de Louvain – Brussels – Belgium. Data from 1985–2013.

It should be noted that reliable disaster data are difficult to obtain. Data from the international disaster database maintained by the Centre for Research on the Epidemiology of Disasters (CRED) of Belgium called "Emergency Events Database" (EM-DAT) differ significantly from numbers obtained from other sources. An example of this is provided for 2012 in Table 2. Differences may be due to EM-DAT criteria for including disasters (scale or impact thresholds for inclusion) and/or underreporting of results.[9]

[9] EM-DAT undercounts both events and consequences, particularly as events occurring in rural areas tend to be under recorded and evaluated. (C. Benson. 2013. personal communication ADB, Manila.)

Table 2: Comparison of EM-DAT and the People's Republic of China Disaster Numbers for 2012[a]

Disaster Type	EM-DAT[b]	PRC Records
Drought	0	17
Inland flood	12	400
Coastal flood/storm surge	0	20
Landslide	1	10,888
Subsidence	0	369
Tropical storm/cyclone	6	138
Winter and local storms	3	16
Natural disaster mortality	802	1,530

PRC = People's Republic of China.

[a] http://news.xinhuanet.com/politics/2012-09/22/c_113168419.htm; http://www.soa.gov.cn/zwgk/hygb/zghyzhgb/zhgb/201303/t20130306_24224.html; and http://www.gzepb.gov.cn/hjzs/201306/P020130610453944170224.pdf. The Ministry of Civil Affairs reported in 2012 that there were about 290 million people affected by various natural disasters, with the total number of fatalities being 1,530 people.

[b] Data from the international disaster database maintained by the Centre for Research on the Epidemiology of Disasters (CRED) of Belgium called "Emergency Events Database" (EM-DAT).

Floods affect the greatest number of people annually—approximately 77 million individuals. In terms of economic damage, floods result in the highest annual damage ($9.25 billion). Flooding can be classified into urban flooding, pluvial flooding (also called flash flooding), fluvial flooding (exceeding river channel capacity resulting in floodplain inundation), waterlogging, and coastal flooding.[10]

Droughts are "characterized by a deficiency in a region's water supply as a result of constantly below average precipitation" over a period of time.[11] In the past, droughts in the PRC have resulted in the death of millions. Improvements in transportation, communications, and response time now mostly limit damage from droughts to economic losses, although the loss of urban water supply presents problems which are increasingly difficult to manage through transport mechanisms with increasing scale. In the PRC, droughts affect approximately 21.6 million people annually. The recent droughts in 2006 reduced crop yield in the north by 12% and affected 18 million people in southern PRC alone through significant economic losses and severe drinking water shortages.[12] Water shortages, particularly in the northern coastal areas of the PRC, have led to "The Special Plan for Seawater Desalination and Utilization." The installed treatment capacity at the end of 2010 was approximately 0.43 million m^3/day with an additional 1.75 million m^3/day under construction, which when completed will bring the number of operating plants up to 57 with a capacity of 2.18 million m^3/day.[13] Droughts cause the second-highest economic loss for the PRC at $3.0 billion annually.

[10] Meteorological Office, UK. 2012. *Climate: Observations, Projections and Impacts, Fact Sheet. Case Study.* http://www.metoffice.gov.uk/media/pdf/7/9/COP18_Factsheet_-_China.pdf

[11] http://www.emdat.be/glossary/9#letterd

[12] Meteorological Office, UK. 2012. *Climate: Observations, Projections and Impacts, Fact Sheet. Case Study.* http://www.metoffice.gov.uk/media/pdf/7/9/COP18_Factsheet_-_China.pdf

[13] J. Peng. 2011. WaterWorld. *Market Report: Developing Desalination in China.* http://www.waterworld.com/articles/wwi/print/volume-25/issue-6/regional-spotlight-asia-pacific/market-report-developing-desalination.html

Extreme storms include cyclones, hurricanes, hailstorms, snowstorms, dust storms, or coastal storm surges. Strong winds associated with cold dry winter and spring winds may cause sand and dust storms in desertified areas. Dust storms are the result of sustained high winds at low levels and a thermally unstable atmospheric stratification lifting dry soil or sand to heights over a kilometer. Most dust storms in the PRC originate in the north-western areas of the Xinjiang Uyghur, the Inner Mongolia Autonomous Region, and Gansu Province. These are ecologically sensitive areas with low precipitation and little vegetation cover. Dust storms are observed with a frequency between 1 and 20 days per year in dry regions with little precipitation in the northern PRC: Tarim Basin in Xinjiang (Talimakan Desert), Hexi Corridor in Gansu, and in Inner Mongolia Autonomous Region. A higher frequency of dust storms is seen in the Tarim Basin, with lower frequency in the east. A recent study showed an approximate 10 year high-low oscillation;[14] however, there is disagreement over the trend in occurrence.[15] Approximately 19.8 million people are affected by extreme storms each year, with damages over $2.27 billion.

Temperature extremes may refer to either cold or heat waves. Cold waves caused by a mass of arctic air moving south and east over the PRC, dropping temperatures by more than 16°C may be associated with snow and sand storms, frost, and ice. Guizhou, Qinghai, Xinjiang, and Yunnan provinces are among the most impacted by increased hail, ice, and snow from winter storms.[16] Heat waves are caused by persistent high pressure across the region, the sinking air acts as a dome trapping heat. In the PRC, a heat wave may result in daytime temperatures up to 40°C; although temperatures of above 50°C have been recorded in the far western regions.[17] Aydingol Lake in the Xinjiang Uyghur Autonomous Region has recorded a maximum temperature of 50.2°C.

B. Secondary Water-Related Disaster Hazards

Landslides and avalanches can be initiated by storms, precipitation, melting permafrost, or glacial melt.[18] Desertification in steep areas, often due to overgrazing or previous agricultural conversion, and increases in rainfall intensity are also linked with increased number of landslides. Higher population density and development of mountainous terrain is increasing the risk from landslide hazards.[19] Geographically, landslide events are mainly distributed in the southern and southwestern PRC, where the main landslide-inducing factors include rainfall, earthquake, and flood. Areas in the provinces of Sichuan, Yunnan, and the eastern part of the Tibet Autonomous Region have been identified as hot spots for

14 Y. Yang et al. 2012. The Variability of Sand-Dust Storm Frequency in North-East Asia from 1980 to 2011. *Acta. Meteor. Sinica*. 27 (1). pp. 119–127.

15 X. Wang et al. 2004. Modern Dust Storms in China: An Overview. *Journal of Arid Environments*. Volume 58 (4). pp. 559–574; and A. Goudie. 2009. Dust Storms: Recent Developments. *Journal of Environmental Management*. (1). pp. 89–94.

16 http://www.stats.gov.cn/english/StatisticalCommuniqu/201302/t20130222_61456.html

17 Extreme temperatures around the world. http://www.mherrera.org/temp.htm

18 C. Huggel, J. Clague, and O. Korup. 2012. Is Climate Change Responsible for Changing Landslide Activity in High Mountains? *Earth Surf. Process. Landforms*. 37 (1). pp. 77–91.

19 Y. Yin. 2011. Recent Catastrophic Landslides and Mitigation in China. *Journal of Rock Mechanics and Geotechnical Engineering*. 3 (1). pp. 10–18.

rainfall landslide hazard.[20] The frequency of landslides in the PRC is highly variable, ranging from none to almost 160.[21] Since 1950, there has been an average of more than 40 landslides per year. The frequency, however, appears to be increasing with an upward trend of about 2%.

Droughts leading to over-extraction of water, permafrost melt, increased karst dissolution from precipitation, clay soil shrinkage, and other factors can result in ground subsidence or collapse. Impacts include potential loss of human life or injuries, building and infrastructure damage, flooding, saline intrusion to groundwater, poor drainage, and loss of agricultural land.

Approximately 50 cities are affected by land subsidence, especially in the Delta region of the Yangtze River, the North China Plain and the Fen-Wei River depression. The extraction of groundwater generally appears to be the primary cause (mineral extraction is a factor in some cities). It should be noted that over-extraction can also be due to poor resource management and demands from increased economic growth exceeding capacity.

A 2003 estimate of the area affected by subsidence, including both urban and rural, was 93,855 square kilometers (km^2). Since 1950, there has been a total estimated loss of CNY450 billion–CNY500 billion ($78 billion–$87 billion); and annual infrastructure damage of about CNY0.8 billion–CNY1.0 billion ($139 million–$173 million).[22] Subsidence has resulted in areas of land below sea level in the coastal region of Tianjin and the Hebei Plain.

These areas are vulnerable to the effects of storm surge. Four tidal surges that occurred respectively in 1985, 1992, 1997, and 2003 in the region, caused damage or destruction of several stretches of seawall, as well as a port, oil field, and fishponds. In the Yangtze Delta region, the function of flood control facilities and the flood discharge capability have been degraded; and polluted water has become trapped in the town area. At the river mouth, saline water moves upstream reducing the water quality.

In Suzhou city, 24 buildings located in a fracture zone created by subsidence have been damaged. In the cities of Datong and Xi'an, pipelines, roads, and bridges are damaged every year. In the Wenning Plain of Zhejiang Province, the land is only 2.5–3.3 meters (m) above sea level; and the groundwater level is controlled at 1.9–2.1 m below ground. Due to over-pumping of groundwater, fields have become flooded during the rainy season; and rice cannot be planted (footnote 25). In addition, new infrastructure is at potential risk—measurements along the Beijing–Tianjin high speed railway have found up to 75 centimeters of subsidence.[23]

The PRC has approximately 3.63 million km^2 of karst, and is subject to karst collapse. Few data are available; but as of 2000, there were more than 1,400 karst collapses distributed

[20] F. Nadim et al. 2006. Global Landslide and Avalanche Hotspots. *Landslides*. 3 (2). pp. 159–173; and C. Liu et al. 2013. Susceptibility Evaluation and Mapping of China's Landslides Based on Multi-Source Data. *Natural Hazards.* (see also footnote 21).

[21] C. Liu et al. 2013. Susceptibility Evaluation and Mapping of China's Landslides Based on Multi-Source Data. *Natural Hazards.*

[22] Y. Yin et al. 2006. *Urbanization and Land Subsidence in China.* IAEG2006 Paper number 31. http://iaeg2006.geolsoc.org.uk/cd/PAPERS/IAEG_031.pdf

[23] M. Eineder and Y. Zhang. 2012. *Mapping Land Subsidence with Multi-Frequency Time Series SAR Images.* Dragon 2 Final Results and Dragon 3 KO Symposium. 25–29 June 2012.

over 22 provinces and about 45,000 collapsed pits.[24] Karst collapses are concentrated in the southern parts of the PRC, including the Guangxi, Guizhou, Jiangxi, Hubei, Hunan, Sichuan, and Yunnan provinces; but they also occur in some northern provinces, such as Hebei, Heilongjiang, Liaoning, and Shandong. Most collapses occurred in highly developed regions such as cities and mines, and the damages were usually very large (about CNY1,500 million annually).

In coastal areas, groundwater systems are connected to the sea and freshwater flow is from the land to the sea. Changes in the hydraulic levels in the groundwater or in the sea can reverse the flow, resulting in saltwater intrusion into the aquifer. Thus, saltwater intrusion into aquifers will be exacerbated by any sea-level rise (SLR).

Over-extraction of coastal groundwater or minerals may also result in saltwater intrusion. Aquifers in the coastal zones of Heibei, Liaoning, and Shandong provinces have been impacted by saltwater intrusion. Thousands of hectares (ha) of farmland have been damaged, and pumping wells have been abandoned. In Laizhou and Longkao cities of Shandong Province, groundwater levels have dropped 10 m below sea level resulting in saltwater intrusion over an area of 360 km^2 with about 2,000 wells abandoned. Along the coastal zone of Laizhou Bay (southern arm of Bohai Sea in Hebei Province), saltwater intrusion affected an area of 40 km^2/year during the 1980s.[25] A study of the groundwater system in Liaodong Bay (the northern bay of the Bohai Sea) coastal plain in Liaoning Province concluded that if all hydrogeological conditions remained as at 2009, saltwater intrusion could be expected in all aquifer layers, threatening water supply systems.[26]

Saltwater intrusion into estuaries has a similar effect, reducing water availability in the lower reaches of rivers by negatively impacting water quality. The southern branch of the Yangtze River is an example of saltwater estuary intrusion. The river connects to Chenhang Reservoir and is the second largest source of fresh water for Shanghai. Since 1999, higher salinity of river water during the dry season has threatened water supplies. The problem increased significantly in 2004 due to increased demand from economic activities.[27] Large-scale saltwater intrusion has also been threatening the freshwater supply of about 15 million people in the metropolitan cities surrounding the Pearl River Delta. An abrupt change in topography due to intensive dredging campaigns in the river networks is probably the most crucial factor leading to the saltwater intrusion in large areas of this delta.[28]

Wildfire incidence may be intensified by droughts, particularly if there is a large fuel load. Historically, forest fires are most common in Hubei, Hunan, and Sichuan provinces; and the incidence rate appears to be falling.[29]

---

24 M. Lei, X. Jiang, and L. Yu. 2002. New Advances in Karst Collapse Research in China. *Environmental Geology.* 42 (5). pp. 462–468.

25 R.M. Llamas and E. Custodio, eds. 2002. *Intensive Use of Groundwater: Challenges and Opportunities.* Taylor and Francis. p. 126.

26 F. Ding et al. 2011. *Numerical Study on Seawater Intrusion into Groundwater in Liaodong Bay Coastal Plain, China.* Volume 1. pp. 725–729. International Symposium on Water Resource and Environmental Protection (ISWREP), 20–22 May 2011.

27 P. Xue et al. 2009. Saltwater Intrusion into the Changjiang River: A Model-Guided Mechanism Study. *Journal of Geophysical Research.* p.114.

28 W. Zhang et al. 2013. Numerical Simulation and Analysis of Saltwater Intrusion Lengths in the Pearl River Delta, China. *Journal of Coastal Research.* 29 (2). pp. 372–382. doi: http://dx.doi.org/10.2112/JCOASTRES-D-12-00068.1.

29 http://www.stats.gov.cn/english/StatisticalCommuniqu/201302/t20130222_61456.html

CHAPTER 3

Climate Change Observations, Projections, and Impacts on Water-Related Disasters

There is a strong expectation for increasing risks of WRD with climate change. Historical climate trends and projections are reviewed here briefly, along with impacts on WRD. Implications for agriculture and food security are addressed in section IV.

A. Observed and Expected Climate Change

1. Climate Observations

Based on data from 1960 to 2010, the general trend has been toward widespread warming, with greater warming occurring in winter than in summer. Temperatures from December to February were estimated to increase between 0.25°C/decade and 0.50°C/decade over much of the PRC as compared with estimated increases of between 0.1°C/decade and 0.25°C/decade during June–August (footnote 12). The number of cool nights per year has decreased since 1960, and is continuing to decrease at a rate of 1.82% per decade. The number of warm nights per year is increasing at a rate of 1.97% per decade.[30]

Annual total precipitation appears to be increasing an average 0.38 mm/decade, as are the number of days with heavy precipitation. Increased precipitation was found to be greater in southern and eastern PRC. However, areas in central PRC were found to have reduced precipitation (footnote 14).

Droughts in the PRC, as measured by a standardized precipitation evapotranspiration index over the period 1950–2010, are reported to have increased since the late 1990s (dry area increasing by ~3.72% per decade) with persistent multiyear severe droughts more frequent in the northern, northeastern, western, and northwestern PRC.[31]

2. Climate Change Projections

Projected changes in temperature by 2100 based on the A1B emissions scenario are generally about 3°C in southeast PRC. [32] Projections are higher, up to about 4.5°C, over the

[30] Cool days and nights are defined as being below the 10th percentile of daily maximum or minimum temperature, and warm days/nights are defined as being above the 90th percentile of the daily maximum or minimum temperature.

[31] M. Yu et al. 2013. Are Droughts Becoming More Frequent or Severe in China Based on the Standardized Precipitation Evapotranspiration. Index: 1951–2010? *Int. J. Climatol.* doi: 10.1002/joc.3701.

[32] The A1 emission scenario is from the Intergovernmental Panel on Climate Change Special Report on Emission Scenarios. The A1 scenario assumes very rapid economic growth, global population that peaks in about 2050 and then declines, and new more efficient technologies.

northern and western PRC.[33] Combined climate models (known as the CMIP3 - Coupled Model Intercomparison Project Phase 3 - ensemble) have good agreement over most of the PRC.[34] The recently released United Nations Intergovernmental Panel on Climate Change Fifth Assessment Report stated similar results.[35]

Annual precipitation is projected to increase for most of the PRC, with increases of up to 20% in the northeastern PRC. In the southeast, increases of between zero and 10% are projected. There is high agreement for CMIP3 models in the northeast, but less agreement in the southeast. Recent studies suggest that higher emissions scenarios project larger changes in precipitation extremes. For example, the current trend of increases in maximum 5-day rainfall is projected to become faster. The historic trend of 2.1 mm/100-year found from the 1961–2000 baseline is projected to increase to 18.8 mm/100-year in the 21st century for the A2 scenario, 15.0 mm/100-year for the A1B scenario, and 8.0 mm/100-year for the B1 scenario.[36] In terms of spatial patterns of change, there was a general increase in most regions of the number of days with precipitation greater than 10 mm.[37]

B. Impacts on Water-Related Disasters

1. Water Stress and Drought

Global-scale studies agree that parts of the PRC currently suffer from a moderate to high level of water stress. Recent research calculates an "Adjusted Human Water Security Threat" indicator, which combines threats to human water security and to biodiversity in waterways.[38] This indicator is designed to reflect the integrated water resources management (IWRM) objective to balance human resource use and ecosystem protection.

The study showed that northern PRC was subject to a high level of threat to human water security (similar to most of India and much of Eastern Europe), while southeastern PRC is at the next lowest level of risk. It also showed that the biodiversity of rivers in central, eastern, and southern PRC was threatened. The combined assessment placed all of the highly populated areas of the PRC in the highest level of the "Adjusted Human Water

---

33 The A1B emissions scenario is an emissions scenario from the Intergovernmental Panel on Climate Change (IPCC) Special Report on Emission Scenarios. This scenario assumes very rapid economic growth, global population that peaks in about 2050 and then declines, and new more efficient technologies, as well as a balanced energy source approach.

34 CMIP3 refers to the assembled model output contributed by leading climate modeling centers around the world for the past, present, and future climate; collected and archived during the years 2005 and 2006; and constitutes phase 3 of the Coupled Model Inter-comparison Project.

35 IPCC. 2014. Impacts, Adaptation and Vulnerability. *Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge, UK; and http://ipcc-wg2.gov/AR5/images/uploads/WG2AR5_SPM_FINAL.pdf

36 A1, A2, and B1 emission scenarios are from the Intergovernmental Panel on Climate Change Special Report on Emission Scenarios. The A1 scenario is described in footnote 32. The A2 scenario assumes that economic development is regionally oriented by self-reliant nations operating independently, and a population that is continuously increasing. The B1 scenario assumes a global population that peaks in about 2050 and then declines (like the A1); but assumes an economy that is focused on service and information, and is environmentally sustainable.

37 Z.H. Jiang et al. 2011. Extreme Climate Events in China: IPCC-AR4 Model Evaluation and Projection. *Climatic Change.* Published online. http://link.springer.com/article/10.1007%2Fs10584-011-0090-0#

38 C.J. Vörösmarty et al. 2010. Global Threats to Human Water Security and River Biodiversity. *Nature.* 467. pp. 555–561.

Security Threat" indicator (on a global basis) as a result of pollution, over-extraction, insufficient water storage, and land degradation.[39]

A recent study estimated annual per capita water resources in the Yellow River basin to be about 430 m^3, significantly less than the 1,000 m^3 value used to define chronic water scarcity by the Falkenmark Index (also referred to as the water stress index).[40] Furthermore, given that demand within the Yellow River basin exceeds 75% of the renewable water resources available, management approaches need to focus on increasing water conservation and efficiency, reducing demand and strengthening the management of all sources of water pollution. The PRC's policy of hard provincial-level targets for water quantity, quality, and water use efficiency and the policy direction toward integrating water quantity and quality permitting is appropriate.

Drought and water stress respond to several factors, including precipitation and evaporation (which is a function of temperature, isolation, humidity, and wind), and land use and management, which affect land cover and infiltration. With both precipitation and temperature projected to increase in the PRC over the next 90 years, there is a chance that water stress and drought will worsen from climate change as well as increased competition for water from growing demands, including the need to better meet ecological requirements.

The United Nations Intergovernmental Panel on Climate Change Fourth Assessment Report noted an increase over recent decades in the area affected by drought, and that this has now exceeded 6.6 million ha since 2000 in Beijing, Hebei Province, Inner Mongolia Autonomous Region, Shanxi Province, and the northern PRC.[41] Some global- and national-scale studies project that water stress could increase in the PRC if temperature increases by about 2°C. However, projected increases in precipitation and runoff under higher warming or higher emission scenarios, while having a potential to cause problems such as flooding and erosion may, if well managed, lead to a decreased water stress. These projected changes in temperature, precipitation, and water stress underlie the variability reported in the projected crop yields. Estimates from the United Kingdom (UK) Met AVOID studies on water stress for the A1B emissions scenario found that, on average, 6% of the PRC's population would be exposed to increased water stress and 20% to decreased water stress by 2100.[42]

2. Pluvial Flooding (Flash Floods) and Rainfall

Extreme precipitation is projected to increase in parts of the PRC. However, increases in daily rainfall extremes will not necessarily result in increases in pluvial flooding. This type of flooding is dependent on multiple factors, including the sub-daily distribution of the rainfall, slope, aspect, soil type, antecedent soil moisture, land cover (degree of tree, shrub and grass

39 ADB's publication *Asian Water Development Outlook 2013* gives estimates for the PRC and other countries in Asia and the Pacific of several dimensions of water security. Information in this publication confirms that there are significant threats to water security in the PRC.

40 C. Ringler et al. 2010. Yellow River Basin: Living with Scarcity. *Water International.* 35. pp. 681–701.

41 IPCC. 2007. *Climate Change 2007: Impacts, Adaptation and Vulnerability.* Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK.

42 AVOID is a research program that provides key advice to the UK government on avoiding dangerous climate change brought on by greenhouse gas emissions. http://www.avoid.uk.net/

cover, area of impervious surfaces in the watershed), capacity and maintenance of artificial drainage systems, etc.

3. Fluvial Flooding (Exceeding River Channel Capacity)

Flooding events have become more frequent in the middle and lower reaches of the Yangtze River, and northwestern PRC, but less frequent in the northwestern reaches of the Yangtze and northeastern PRC.[43] Discharge during the summer flood season has risen significantly, which has been associated with an increase in the number of flooding events over the past 40 years. Human activities such as land clearing, land reclamation, and construction of levees have reduced lake sizes and have filled river beds, thus reducing the flood storage capacity of lakes and the sizes of the fluvial channels.[44]

Climate change impact studies have obtained highly variable results, ranging from a 20% decline to an 80% increase in flood risk for the PRC by 2030 from climate change alone. The mean across all projections is approximately a 10% increase in flood risk by 2030. By 2100, the mean of all projections is a 20% increase; and the highest increase is nearly 150%.[45]

Recent research confirms the recorded increase in flooding in the PRC, particularly fluvial flooding, however, it is not possible to attribute this increase to climate change alone. Flood predictions from climate change modeling studies reflect the high sensitivity and nature of the relationship between different climates and flood characteristics, which are not solely influenced or caused by climate change alone.[46]

4. Tropical Cyclones

It is unclear how climate change will affect the frequency of tropical cyclones. Projections of changes in cyclone frequency are highly uncertain. Some experimental modeling in western Pacific tropical cyclones projected decreases of 20%–28%.[47] However, increases in the number of tropical cyclones tracking close to the coast of the PRC have been observed, reportedly due to a northward shift in the dominant region for formation of cyclones in the West Pacific.[48] An increase in tropical cyclone activity in the western Pacific basin has also been observed over the last decade, although whether such a shift is due to natural variability or anthropogenic climate change is currently unclear.[49]

---

[43] P.M. Zhai et al. 2005. Trends in Total Precipitation and Frequency of Daily Precipitation Extremes over China. *Journal of Climate.* 18. pp.1,096–1,108.; and B. Su, M. Gemmer, and T. Jiang. 2008. Spatial and Temporal Variation of Extreme Precipitation over the Yangtze River Basin. *Quaternary International.* 186. pp. 22–31.

[44] T. Jiang, B. Su, and H. Hartmann. 2007. Temporal and Spatial Trends of Precipitation and River Flow in the Yangtze River Basin, 1961–2000. *Geomorphology.* 85. pp. 143–154; Q. Zhan et al. 2006. Observed Trends of Annual Maximum Water Level and Streamflow during Past 130 Years in the Yangtze River Basin, China. *Journal of Hydrology. 324.* pp. 255–265; Z.X. Zhang et al. 2009. Atmospheric Moisture Budget and Floods in the Yangtze River Basin, China. *Theoretical and Applied Climatology.* 95. pp. 331–340.

[45] R. Warren, et al. 2010. The Economics and Climate, Change Impacts of Various Greenhouse Gas Emissions Pathways: A Comparison between Baseline and Policy Emissions Scenarios. *AVOID Report.* AV/WS1/D3/R01. http://www.metoffice.gov.uk/avoid/files/resources-researchers/AVOID_WS1_D3_01_20100122.pdf

[46] Z.W. Kundzewicz et al. 2012. Flood Risk and Climate Change: Global and Regional Perspectives. *Hydrological Sciences Journal.* 59 (1). pp. 1–28.

[47] L. Bengtsson et al. 2007. How May Tropical Cyclones Change in a Warmer Climate? *Tellus* A. 59. pp. 539–561.

[48] K.A. Emanuel, R. Sundararajan, and J. Williams. 2008. Hurricanes and Global Warming: Results from Downscaling IPCC AR4 Simulations. *Bulletin of the American Meteorological Society.* 89. pp. 347–367.

[49] J.Y. Tu, C. Chou, and P.-S. Chu. 2009. *Journal of Climate.* 22. pp. 3,617–3,628.

The intensity of cyclones in the western Pacific basin, however, has been projected to increase considerably by a number of global- and regional-scale studies.[50] Thus, climate change may cause tropical-cyclone damage in the PRC to increase, even if the frequency of tropical cyclones decreases.[51] There are some 15 large urban areas in the current area affected by cyclones, which extends from Hainan to Shandong provinces.

5. Coastal Regions

Recent global-scale assessments of SLR suggest that the PRC may experience among the most severe coastal impacts. Results for the PRC showed that 15 ports were affected, with 17.1 million (2030) to 27.7 million (2070) people estimated to be potentially affected. This is the largest absolute increase in exposure to SLR by 2070 relative to the present day of any of the countries studied.[52]

Another study of the impact of a 10% intensification of the current 1-in-100-year storm surge combined with a 1 m SLR estimated that about 17% of the PRC's coastal land area, a coastal population of about 10.8 million people, about 40% of coastal wetlands, and about $31 billion of the PRC's GDP could be affected.[53]

The costs of coastal adaptation to climate change have been previously studied in the PRC, with an engineering approach recommended based on the long history of hard protection and land reclamation in the region.[54] The actions costed in this study were (i) sea dike construction and upgrades, including maintenance costs for impacts of coastal flooding; (ii) beach nourishment; and (iii) raising port levels to enable their continued effective operation. The medium annual adaptation cost for the PRC was estimated at $1.05 billion, excluding the costs to maintain existing sea dikes (which was estimated at $2.3 billion per year), with the majority of that cost being for the construction and upgrade of sea dikes. The study considered coastal subsidence but made no additional cost allowance. It noted the high awareness and significant action already being taken to manage this issue.

50 K. Oouchi et al. 2006. Tropical Cyclone Climatology in a Global-Warming Climate as Simulated in a 20 km-Mesh Global Atmospheric Model: Frequency and Wind Intensity Analyses. *Journal of the Meteorological Society of Japan.* 84. pp. 259–276; and M. Stowasser, Y. Wang, and K. Hamilton. 2007. Tropical Cyclone Changes in the Western North Pacific in a Global Warming Scenario. *Journal of Climate.* 20. pp. 2,378–2,396.

51 R. Mendelsohn et al. 2012. The Impact of Climate Change on Global Tropical Cyclone Damages. *Nature Climate Change.* 2. pp. 205–209.

52 S. Hanson et al. 2011. A Global Ranking of Port Cities with High Exposure to Climate Extremes. *Climatic Change.* 104. pp. 89–111.

53 S. Dasgupta et al. 2009. *Sea-Level Rise and Storm Surges: A Comparative Analysis of Impacts in Developing Countries.* Washington, DC: World Bank. pp. 1–41.

54 ADB. 2013. *Cost of Adaptation to Rising Coastal Water Levels for the People's Republic of China, Japan, and the Republic of Korea.* http://www.adb.org/sites/default/files/pub/2013/cost-adaptation-rising-coastal-water-levels-prc-jap-kor.pdf

CHAPTER 4

Analysis of Risks, Exposure, Vulnerability, Trends, and Implications for Human Health and Food Security

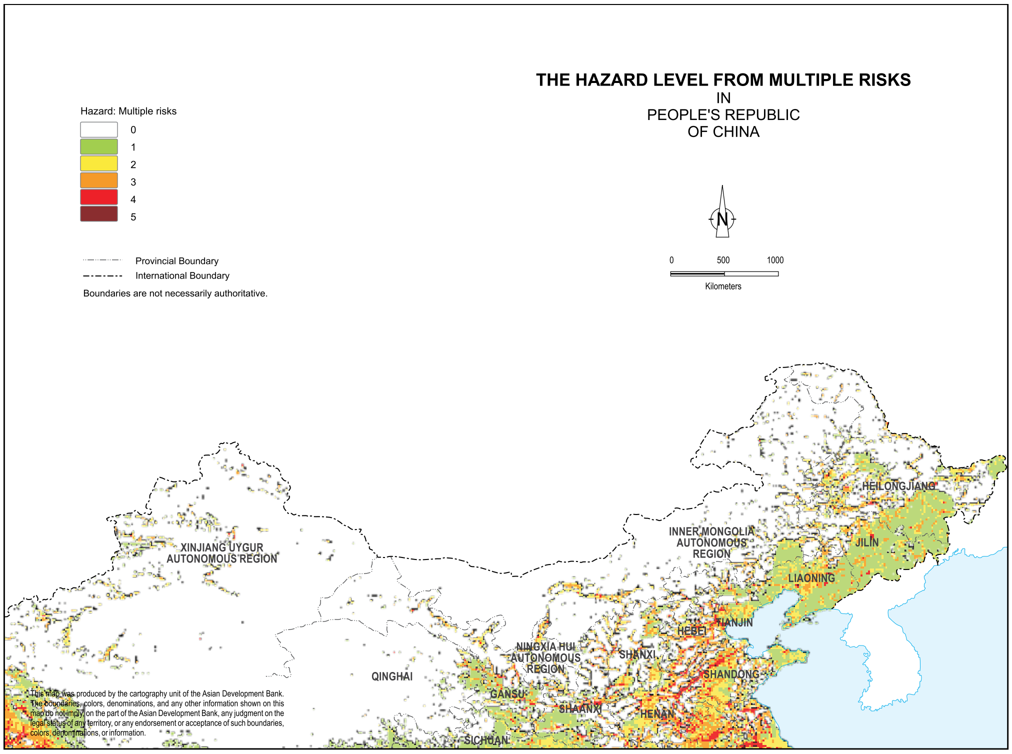
A. Spatial Distribution of Disaster Risks

The Global Risk Data Platform (GRID) provides data on the spatial distribution of disaster risks.[55] Figure 1 shows the relative risk level induced by multiple hazards such as tropical cyclone, flood, and landslides induced by precipitations. The unit is an estimated risk index ranging from 1 (low) to 5 (extreme). As indicated on the map, the areas which are at highest risk are along the Yangtze and Huang He rivers, and the eastern coastline of PRC including Shanghai and Beijing cities as well as Jiangsu, Shandong, Henan, Hebi, Tainjin, Guangdong, and Sichuan provinces. Overall there is a large portion of the PRC which is at a moderate or higher risk of multiple hazards. The risk levels from the individual hazards of flood, cyclone, and wet landslide are shown in Appendix 2.

The vulnerability of the PRC to the risks (Figure 1) is related to the exposure (Figures 2–4), which is a measure of the people and property at risk of a water related disaster. The PRC is vulnerable to the impacts of hazards, primarily due to the geographical distribution of its population and physical and/or economic assets (e.g., infrastructure, agricultural crops) in areas identified as at risk from future climate-related disasters and significantly higher temperatures. The forecast of the population density for the PRC (Figure 2), the main production areas (Figure 3), and location of urban assets (Figure 4) show a similar spatial distribution with concentrations along the southeastern coastline; provinces of Jiangsu, Shandong, Henan, Hebei, and Guangdong; and major cities Shanghai and Beijing. As people live in, are productive in, and have their assets located in locations which have hazard risk, they are exposed.

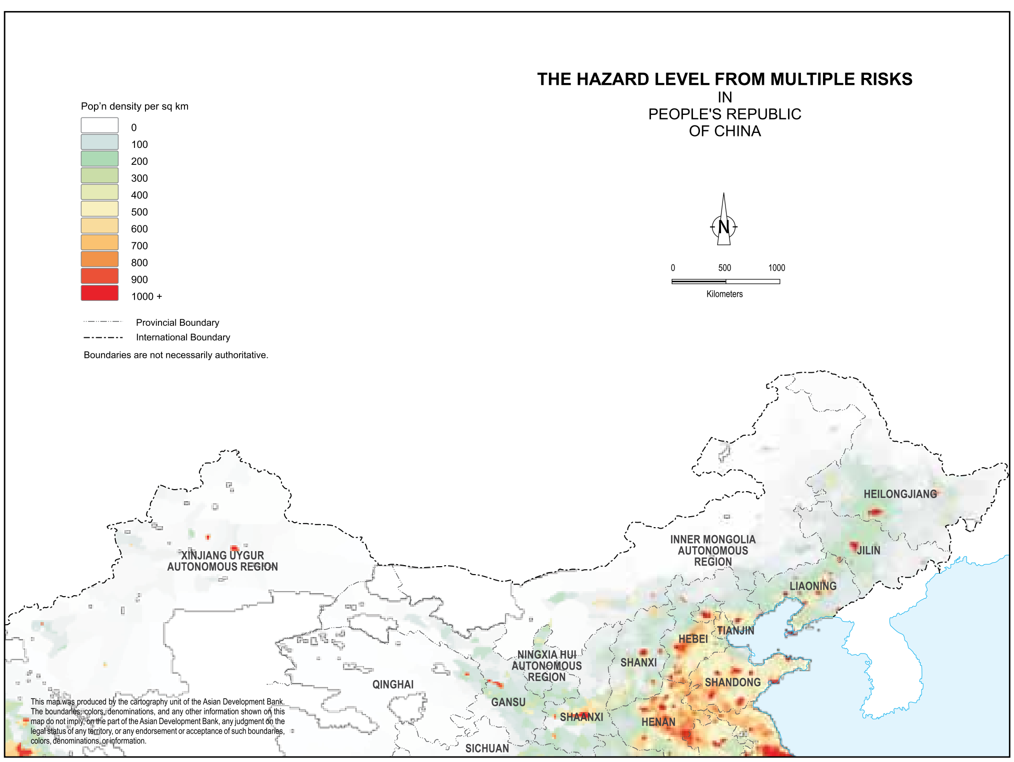
55 http://preview.grid.unep.ch/index.php

Figure 1: Multiple Risks



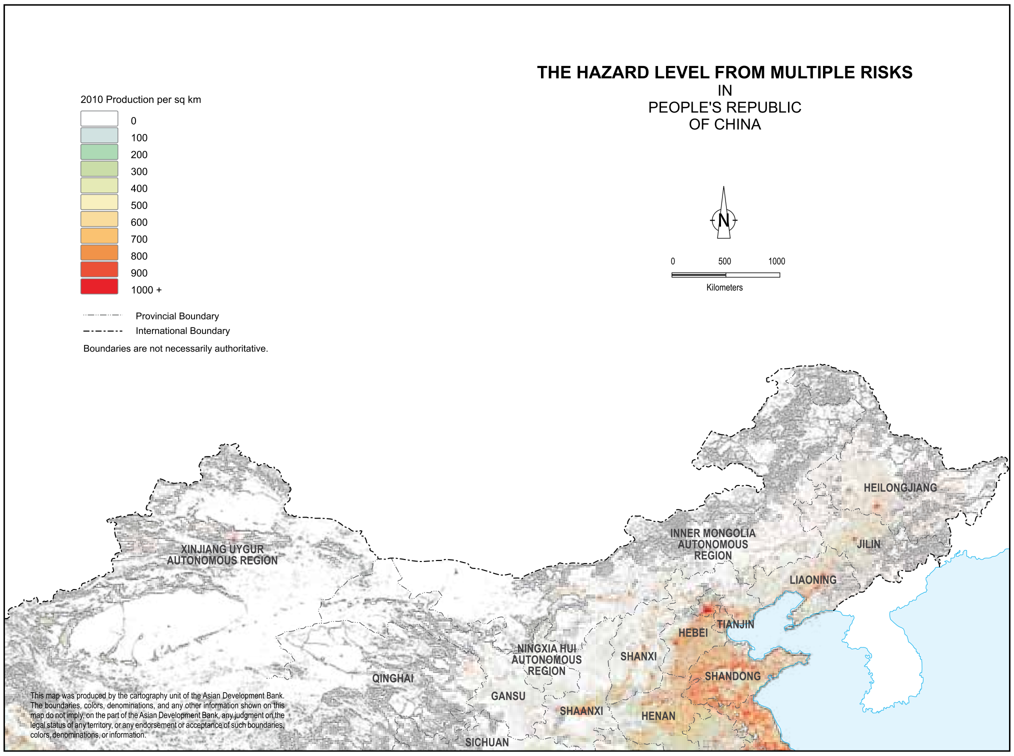
Source: Map by H. Milner, data from the Global Risk Data Platform (GRID), boundaries are approximate.

Figure 2: Forecast Population, 2010



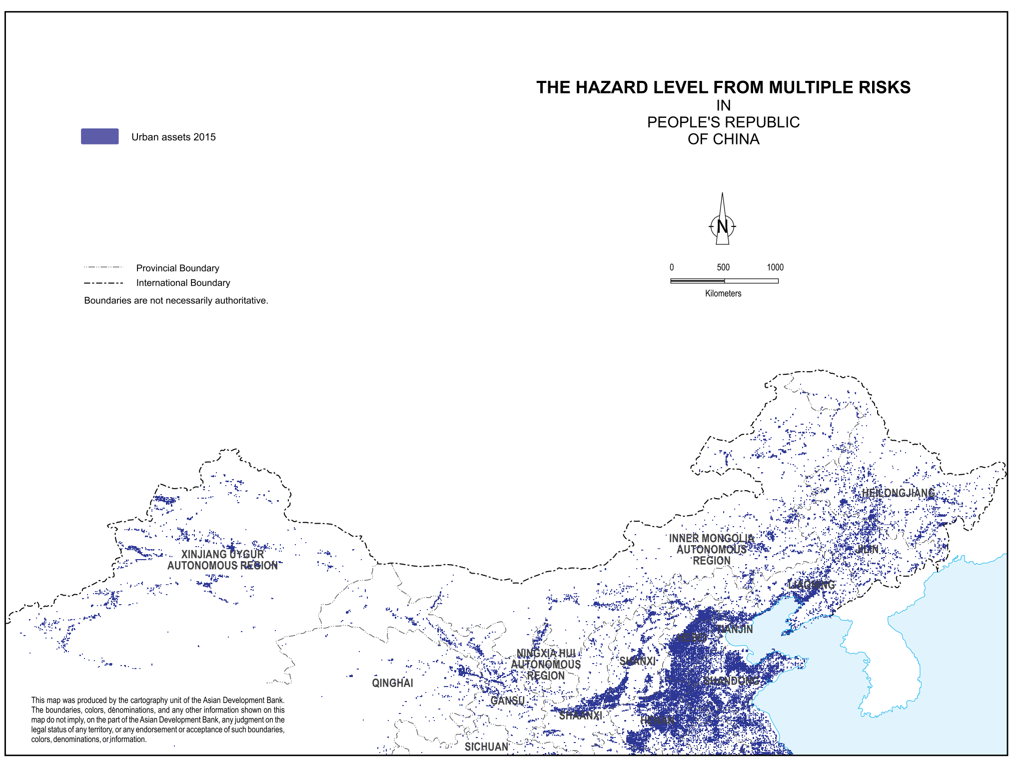
Source: Mapping by H. Milner, data from the Gridded Population of the World, forecast on the basis of data from the United Nations for 1990, 1995, and 2000. Boundaries are approximate.

Figure 3: Production per Square Kilometer in 2010



Source: Mapping by H. Milner, data from the Global Risk Data Platform (GRID), boundaries are approximate.

Figure 4: The Location of Urban Assets in the People's Republic of China



Source: Mapping by H. Milner, data from the Global Risk Data Platform (GRID), boundaries are approximate.

B. Water-Related Disaster Trends

EM-DAT data on disaster occurrences in the PRC support an apparent increasing trend overall. The average annual number of occurrences for natural disasters for each decade is shown in Table 3.

Table 3: Average Number of Occurrence of Annual Disasters in the PRC (EM-DAT)

1980–1989	1990–1999	2000–2009	2010–2013
11.00	18.00	28.60	26.75

Source: Data from the international disaster database maintained by the Centre for Research on the Epidemiology of Disasters (CRED) of Belgium called "Emergency Events Database" (EM-DAT).

Flood trends are complex. Inland floods are impacting an increasing number of people in a smaller number of houses, while coastal floods are affecting fewer people in fewer houses. For nonresidential buildings, there is an increasing trend for both coastal and inland floods. Livestock, both hooved and avian, are increasingly affected by flooding. The economic impacts of floods are decreasing in inland areas, but increasing in coastal areas. However, both EM-DAT and national data are in agreement that the flood mortality and the number of people who were affected by floods are decreasing; while the total costs associated with flood damages remain level. These trends are influenced by many factors: population movements (east toward the coast); rural–urban migration; urban growth; economic, industrial, and commercial development; better flood management; and strengthened disaster response as well as changes in the hydrology.

Based on the EM-DAT data, there is no apparent trend in the occurrence of droughts, the number of people affected by droughts, or the damage caused by drought in the PRC. The lack of accurate end dates for droughts prevents any assessment of trend in drought length, and the number of droughts that resulted in human loss of life is too small to make any assessment of such trend. However, national sources indicate that the number of droughts, impacts on livestock, and damage from drought are all increasing, while the number of people and number of hectares affected by drought are decreasing. These trends are likely influenced by management actions being taken to address drought and the increasing total volume of water storage available.

The number, mortality rate, and the number of people affected by wet landslides are increasing according to EM-DAT data. While there is inadequate data to make a firm prediction, the cost of damage by wet landslides seems to be increasing. National data on landslides and subsidence are in agreement. The trend in impacts of landslides on non-residential buildings is level, but that for subsidence is increasing. Hooved and avian livestock are increasingly being affected by landslides and subsidence. While the number of hectares affected by landslides is declining, the number of hectares affected by subsidence is increasing.

EM-DAT data show the mortality resulting from local storms is decreasing, while the number affected by such storms remains almost constant. The damage cost from local storms, however, is rising. Mortality from tropical cyclones is also decreasing; while the number affected by tropical cyclones is increasing, as is the cost of damage by cyclones. An analysis of the data on storms, where the type of storm is unspecified, shows the same trend as tropical cyclones.

National data on tropical cyclones, however, finds that these are increasingly frequent; although the losses resulting from cyclones are remaining constant. The area affected and the number of individual rooms damaged is decreasing, but the numbers of people and livestock affected and the number of nonresidential buildings damaged by cyclones is increasing.

National data on hailstorms, severe ice, and snow show that the number of such events is increasing, but the number of people and residences affected is staying level. The number of nonresidential buildings affected by severe hail, ice, or snow is increasing, as are the numbers of hooved and avian livestock affected. While the number of hectares affected by severe hail, ice, or snow is increasing, the total damage from these events is falling.

Data on wildfires, subsidence, and saltwater are too limited to support any conclusion about trends from EM-DAT, although national data show that the number of forest fires is falling.

C. Implications of Water-Related Disasters for Human Health and Food Security

1. Waterborne and Water-Related Diseases

Increases in waterborne diseases, such as typhoid fever, cholera, leptospirosis, and hepatitis A, may result from flooding, through pollution of drinking water sources and increases in vector-borne diseases, such as malaria, dengue and dengue hemorrhagic fever, and Japanese encephalitis. Extreme storms may result in damage to infrastructure resulting in the failure of drinking water and sanitation services. WRD management actions which reduce the hazards, risks of drought and flood, and risks from extreme storms could lessen the above impacts.

In the past, droughts have caused ill-health and deaths because they often trigger and exacerbate malnutrition and famine, and water supply was inadequate. Floods now have an increasing impact, while drought impacts are decreasing. Both flood and drought may limit sanitary practices such as hand and face washing (increasing potential transmission of diseases such as diarrhea, trachoma) or result in the use of unsafe water causing increases in a range of ailments. Drought impacts may possibly include arsenic poisoning and fluorosis, if alternative problem sources are returned to service to maintain supply during drought periods.

Estimates of the burden of disease at the provincial level found that unsafe water, poor sanitation and hygiene accounted for 2.81 million disability-adjusted life years (DALYs) (where one DALY is equivalent to one lost year of "healthy life") and 62,800 deaths in the country in 2008.[56] Children less than 5 years of age accounted for 83% of the DALYs. Per capita DALYs were shown to increase along an east–west gradient, with the highest burden in inland provinces, which have the lowest income per capita. While not all of these disease impacts are related to occurrence of disasters, the study demonstrates the burden of disease, the disproportionate impact on young children, and a wide variation between provinces and communities within provinces. The poorest in the community have limited ability to respond effectively to the outbreak of waterborne and water-related diseases.

The PRC's rural population, comprising 47% of the total population, is served by only 37.5% of the nation's trained health workers. Lack of affordable health care and increasingly degraded water make the burden of disease much greater in the countryside. Typhoid (fever) is endemic in southern PRC and remains a public health problem despite recent progress in water and sanitation coverage.[57]

In areas dependent on desalinization plants, harmful algal 'blooms' brought about by the combination of warming waters and fertilization inputs (also jellyfish and seaweed) can restrict operations by clogging filters and fouling surfaces that can compromise the integrity of reverse osmosis membranes, or that can cause taste and odor problems.[58] There is also concern over the potential of neurotoxins from some algae to persist in desalinated water.

Improvements in infrastructure for water supply, sewerage, and treatment systems in health services are required. These improvements should target provinces with lower rates of economic development. In addition, there is a need for improved monitoring, increased transparency, and regulatory oversight to better estimate the effects of contaminated water, and poor sanitation and hygiene on human health (footnote 56). Such infrastructure, monitoring, and regulatory oversight would also significantly strengthen resilience to WRD.

2. Fisheries Production

Coastal and inland fisheries production are potentially affected through (i) damage to capture fisheries infrastructure and transport; (ii) increased sedimentation of fish habitat areas in rivers, wetland and lakes, and seagrass and shellfish beds in shallow coastal waters; (iii) algal blooms; (iv) river and coastal pollution due to flooding; (v) decreased productivity due to droughts; (vi) reductions in fish stock arising from dams and dikes restricting access to fish breeding areas; and (vii) changes in reproductive behavior as a result of flow regulation for flood and drought risk reduction.

---

[56] E.J. Carlton et al. 2012. Regional Disparities in the Burden of Disease Attributable to Unsafe Water and Poor Sanitation in China. *Bulletin, World Health Organization.* 90. pp. 578–587. doi:10.2471/BLT.11.098343. http://www.who.int/bulletin/volumes/90/8/11-098343.pdf

[57] C.E. Boyle. 2007. A China Environmental Health Project Research Brief: Water-Borne Illness in China. Wilson Center, China Environment Forum. Washington, DC; and http://www.wilsoncenter.org/sites/default/ files/waterborne_Aug07.pdf

[58] D.M. Anderson and S. McCarthy. 2012. Expert Workshop on Red Tides and Harmful Algal Blooms: Impacts on Desalination Operations. Middle East Desalination Research Center, National Center of Excellence, Oman. 8–9 February 2012. http://www.medrc.org/download/Habs_and_desaliantion_workshop_report_ final.pdf

National data on the impact of disasters on fisheries production activities show an increasing number of fisheries production affected by drought, but the number affected by severe storms, cyclones, and subsidence is maintaining a level trend. The loss in production from fisheries impacted by disasters is increasing; and although the number of fishponds is increasing, the number of hectares affected by natural disasters remains constant. In 2012, for example, production losses were approximately 5.1 million tons, with 1.6 million ha affected (footnote 12).

The PRC uses about 34 million tons of fisheries products for food and about 3 million tons for feed and oil.[59] Consumption of fish in the PRC has risen rapidly in recent decades, while its fish production rose from 7% in 1961 to 35% of the global total of 148 million tons in 2010.

The PRC accounted for more than 60% of global aquaculture production volume in 2010, with almost 14 million people engaged as fishers and fish farmers. Aquaculture production, which has grown to match the increased consumption, is vulnerable to adverse impacts of disease and environmental conditions. In 2010, aquaculture production losses in the PRC were estimated at 1.7 million tons (worth $3.3 billion), with most losses attributable to natural disasters (1.2 million tons worth around $600 million). As stated above, production losses in 2012 were significantly higher than those recorded in 2010, and these losses are projected to increase further with climate change.

Rice–fish farming is an important and long-standing fisheries production process in the PRC, which is expected to be impacted by increased droughts with climate change. The PRC has 1.3 million hectares of rice fields with different forms of fish culture, which produced 1.2 million tons of fish and other aquatic animals in 2010.[60]

The PRC accounted for over 20% of inland capture fisheries production (>18 million tons) and is working to improve data available on marine capture production. Capture fisheries are at risk from cyclones, which are projected to increase in intensity, although perhaps not in frequency.

Marine fisheries production in the PRC is affected by harmful algal blooms: red and brown tides in the south, and green tides in the north. Such 'blooms' are more common in particular months, appear to be associated with high nutrient levels, which may result from wastewater and sewage discharge, and may also be more likely after heavy local runoff. Algal blooms may occur, and perhaps are more likely, during a river basin-wide drought and could increase in frequency of occurrence with higher sea temperatures projected with climate change.

The frequency of these blooms has been reported to be increasing along the PRC coast. In the last 20 years, the coastal region has been subjected to an average of 83 red tides a year. Coastal fisheries are also impacted by a brown tide caused by another type of algae. The third occurrence of a brown tide, first noticed in the PRC's seas in 2009, affected 3,350 km^2 by July 2012, the largest area recorded in the world. Scallop, oyster, and mussel

59 Information on fisheries productivity is from the Food and Agriculture Organization of the United Nations (FAO). 2012. *The State of World Fisheries and Aquaculture.* http://www.fao.org/docrep/016/i2727e/i2727e.pdf

60 FAO. 2012. *The State of World Fisheries and Aquaculture.* http://www.fao.org/docrep/016/i2727e/i2727e.pdf

farming were impacted.[61] Projected increases in sea surface temperatures will further increase the occurrence of blooms, unless nutrient inputs from wastewater and sewage discharge and from agricultural runoff are controlled.

3. Agricultural Production

Reductions in agricultural production may result from droughts, floods, extreme storms, and extreme weather (either hot or cold). WRD management to reduce hazards and risks will improve agricultural productivity.

The Food and Agriculture Organization of the United Nations (FAO) estimated total world agricultural production for 2011 at 6,795 billion tons with a total value of about $1,529 billion.[62] Agricultural production has been growing at a rate of 2.1% per year since 2003. The growth rate is forecast to fall to 1.5% over the next decade. It should be noted, however, that although the demand growth rate is slowing, the total agricultural production required is still increasing.

The PRC's agricultural production of 1,151 billion tons in 2011 has been increasing consistently over the past 10 years at a rate of almost 3.3%. Being the staple crop of the PRC, rice is the largest crop in both production and total value is also increasing, although at a slower rate of about 3%. The 2011 production of rice was estimated at just over 201 billion tons.

Although the picture is mixed, global- and regional-scale studies generally project decreases in the yield of the PRC's major crops (rice, wheat, and maize) as a consequence of climate change. Those studies that also consider water availability are all significantly more pessimistic with regard to food security in the PRC but they considered only current cropland. It should be noted that some areas, which are not currently used as cropland, may become suitable for such use as a result of climate change. A study which considered possible changes in cropland with climate change gave a mean projection that, by 2030, 15% of current cropland would become less suitable, and 15% would become more suitable for crop production, but with large variations between climate models.[63]

Playing into this picture of decreasing crop yield in the PRC are two other factors: SLR, which will potentially impact those grain producing areas in Pearl and Yangtze river deltas and in coastal areas of Jiangsu Province and the west rim of the Bo Hai Sea; and the switch of the PRC from being a net exporter to a major importer of maize and soybeans, associated with dietary change with higher incomes.[64]

---

[61] L. Clark. 2012. Chinese Survey Reveals Heavy Coastal Pollution, Red Tides, and Water Shortages. *Wired UK, Science*. http://www.wired.co.uk/news/archive/2012-11/07/chinese-water-pollution

[62] Agricultural Production Information. http://faostat.fao.org/site/339/default.aspx

[63] Met Office UK, 2012. Climate: Observations, Projections and Impacts, China. http://www.metoffice.gov.uk/media/pdf/7/9/COP18_Factsheet_-_China.pdf pages 91–104.

[64] ADB. 2013. *Food Security in Asia and the Pacific*. http://www.adb.org/sites/default/files/publication/30349/food-security-asia-pacific.pdf

4. Monitoring Production and Losses

The PRC has a comprehensive program for crop monitoring: Cropwatch.[65] It monitors land use; crop planting and growth; environmental indices; flood, drought, and pest disasters; and land desertification using on-ground and remote sensing methods.

The system involves government departments, universities, and research agencies; and operates at timescales of 10 days to a year. Information from this monitoring is used to respond to disasters and to reduce the losses resulting from WRD, including providing advice to farmers.

Crop production loss estimates are prepared jointly by the Ministry of Agriculture (MOA), the Ministry of Civil Affairs, the Ministry of Water Resources (MWR), the Meteorological Administration, and the National Bureau of Statistics. These units obtain, compare, exchange, and evaluate the PRC's agricultural natural disaster data through a combination of sampling surveys and administrative reporting systems.

5. Insurance

Although there is aquaculture insurance available in some provinces, it is not universally offered. The gap between demand and supply of aquaculture insurance services has widened in recent years.[66] High loss ratios from typhoons and high temperatures make commercial insurers reluctant to enter this sector.[67]

An analysis of agricultural insurance in the PRC found strong interest in the scheme by farmers, but also identified a number of constraints including the need for supporting legislation, clearer definition of the government's role, and a poorly developed business network.[68] Researchers from Beijing Normal University surveyed people's risk awareness, insurance acceptance, their opinions on governmental measures for disaster management, and their willingness to pay for disaster house insurance. Respondents from poverty-stricken or less-developed counties were receptive to purchasing natural disaster insurance, but fewer could actually afford insurance. In general, respondents had accurate perceptions regarding threats posed by natural disasters in their area; however, people from regions with a greater multi-hazard threat showed less willingness to purchase disaster insurance because they expected the government to cover losses.[69]

6. Food Security

The PRC currently has relatively low levels of undernourishment (between 5% and 9% of the population). Global-scale studies of food security vary in their conclusions for the PRC;

---

65 http://www.cropwatch.com.cn/htm/en/index.shtml

66 L. Yong, L. Le, and P. Ying. 2006. The Current State of Aquaculture Insurance in China. In FAO. 2006. *Review of the Current State of World Aquaculture Insurance.* http://www.fao.org/docrep/009/a0583e/ a0583e06.htm

67 M. Godfrey. 2014. *China Government Wants Solution to Aquaculture Insurance Conundrums.* http://www.seafoodsource.com/news/aquaculture/26415-china-government-wants-solution-to-aquaculture-insurance-conundrums

68 M. Wang et al. 2011. Agriculture Insurance in China: History, Experience, and Lessons Learned. *Int. J. Disaster Risk Sci.* 2 (2). pp. 10–22. doi:10.1007/s13753-011-0007-6.

69 M. Wang et al. 2012. Are People Willing to Buy Natural Disaster Insurance in China? Risk Awareness, Insurance Acceptance, and Willingness to Pay. *Risk Analysis.* 32 (10). pp.1,717–1,740.

however, they generally project that the country will become less food secure with climate change. The PRC could be a food-importing country as of 2050.[70]

National-scale studies confirm the uncertainty in food security estimates with some suggesting that the PRC could experience large food shortages, while others suggest that it may not face pressures on food security with climate change, at least in the next two decades.[71] However, a recent forecast of food security in the PRC, arguing that the PRC could not rely on imported food, suggested that "in 2030 the food security index[72] will drop from +24 % in 2009 to −4.5 % and +10.2 % under A2 and B2 scenarios, respectively." By 2050, "the food security index is predicted to increase to +7.1 % and +20.0 % under A2 and B2 scenarios, respectively, but this increase will be achieved only with the projected decrease of Chinese population."[73]

None of the studies reviewed considered competition for water from the industry and energy sectors. Water use is increasing in these sectors by approximately 4% per year, reducing the water available for crop production.

---

70 M. Falkenmark, J. Rockström, and L. Karlberg. 2009. Present and Future Water Requirements for Feeding Humanity. *Food Security.* 1. pp. 59–69.

71 W. Wu et al. 2011. Scenario-based Assessment of Future Food Security. *Journal of Geographical Sciences.* 21. pp. 3–17. and D.B. Lobell, et al. 2008. Prioritizing Climate Change Adaptation Needs for Food Security in 2030. *Science.* 319. pp. 607–610.

72 Food security index was defined in the study as $FSI=\frac{\frac{s}{g}-d}{d}$ where *s* is the per capita food supply, *d* is the per capita food demand, and *g* is the expected food self-sufficiency level (g = 0.95).

73 L. Ye et al. 2013. Climate Change Impact on China Food Security in 2050. *Agronomy for Sustainable Development.* April. 33 (2). pp. 363–374. http://link.springer.com/article/10.1007%2Fs13593-012-0102-0

CHAPTER 5

Management of Water-Related Disaster Risks in the People's Republic of China

A. Legislative Base for Management

More than 30 laws and regulations related to disaster reduction have been passed and these provide a comprehensive basis for the management of disaster response. While these laws cover the full range of disaster prevention and disaster reduction, their development has been guided by the traditional principle of "one law for one event" and each law or regulation targets one type of disaster event. The staff of individual agencies responsible for DRM is generally familiar only with the laws and regulations specific to their event type or types.

In October 2013, the PRC's State Council issued a *Notice on the Approach to Emergency Preparedness*.[74] The notice requires governments at all levels to prepare standardized emergency plans involving their departments, grassroots organizations, enterprises, institutions, and social organizations; and encourages the joint preparation of regional or basin-wide emergency contingency plans. Plans are to be based on risk assessment and investigation of emergency resources and are to be prepared in a participatory manner through working groups. Some disaster-related laws specify that there should be insurance schemes, and there have been some trials of natural disaster insurance for agricultural production and farmer's house insurance.[75]

B. Hyogo Framework for Action 2005–2015

The PRC has been working to strengthen its DRM in line with the Hyogo Framework for Action 2005–2015.[76] The scope of this framework encompasses disasters caused by hazards of natural origin and related environmental and technological hazards and risks.

The PRC has made significant progress in clarifying its medium- and long-term strategic goals under this framework. These are to establish a relatively complete working system

[74] PRC State Council. 2013. *State Council Notice on the Approach to Emergency Preparedness.* SCS [2013]. No. 101. http://www.gov.cn/zwgk/2013-11/08/content_2524119.htm#

[75] M. Wang. 2010. *Natural Disaster Insurance in China: Practice and Lessons Learned.* Global Risk Forum, Davos, 11 June 2010. http://www.slideshare.net/GRFDavos/idrc2010mingwangpptx

[76] PRC Ministry of Civil Affairs. 2012. *National Progress Report on the Implementation of the Hyogo Framework for Action (2011–2013) – Interim.* Beijing. http://www.preventionweb.net/english/hyogo/progress/reports/ v.php?id=28446&pid:223

for disaster reduction; to enhance capabilities for disaster monitoring and early warning, prevention and preparation, emergency handling, disaster relief, and rehabilitation and reconstruction; to raise public awareness of disaster reduction and emergency rescue skills; and to significantly reduce human casualties and direct economic losses caused by natural disasters.

At the recent Third World Conference on Disaster Reduction, the Minister for Civil Affairs of the PRC reconfirmed its commitment to (i) comprehensive disaster reduction with socioeconomic development, (ii) adapting to climate change and building disaster reduction into rural and urban development, and (iii) placing people at the central consideration.[77]

C. The People's Republic of China's Current Management System for Disasters

The State Council provides overall leadership and guidance in managing disaster risk. Local governments are responsible for leading all response actions, with the responsibilities of relevant government agencies assigned per the national emergency response plans. During severe disasters, at the central government level, the National Coordination Office for Disaster Mitigation and Relief coordinates the National Committee for Disaster Reduction, the State Flood Control and Drought Relief Headquarters, the PRC Earthquake Administration, the Forest Fire Control Office, and the State Forestry Administration. A table showing the roles and responsibilities of the Flood Control and Drought Relief Office and the major associated roles and responsibilities of agencies is provided in Appendix 3.

DRM procedures have been developed to prevent, reduce, prepare, alert, respond to, and recover from disasters. The task of developing disaster management plans is divided between government agencies according to their specific responsibilities and administrative responsibility areas.

Emergency management following a disaster is the responsibility of local governments: the administrative heads of these governments take overall responsibility for the management of emergencies.[78] These administrative heads direct and coordinate actions during and after the emergency, including with operational departments like the military, water resources, transport, and communications. This institutional arrangement guarantees the effectiveness of emergency management. The costs of maintaining and implementing disaster response mechanisms include hardship allowances, donations by citizens of the PRC, and the cost of stabilizing food production and prices.[79] Prevention planning to reduce future disaster losses, however, is fragmented, even within an area defined for emergency management, such as flood and drought.

[77] PRC Ministry of Civil Affairs. 2015. *Official Statement from Ministry of Civil Affairs at Third World Conference on Disaster Reduction.* Sendai, Japan, 14–18 March 2015.

[78] More recently, there has been encouragement to also involve public and nongovernment agencies. http://www.asifma.org/uploadedFiles/Resources/PRC-12th-FYP(1).pdf

[79] Q. Zhang. 2011. How to Fight Natural Disasters. *China Daily.* 28 June 2011. http://www.adb.org/ news/op-ed/how-fight-natural-disasters

The PRC approach to disaster has been primarily reactive, although this is changing. It monitors the situation, and when the onset of a disaster is perceived, it searches for emergency measures to be adopted and implements these measures. This may be related to their approach to disaster loss estimation. Loss estimates are generally available only for the primary impacts: the losses of people, property, and infrastructure in the immediate disaster area which can be directly attributed to the disaster event. Assessments of indirect losses and macro-economic effects are rarely addressed.

D. Flood and Drought Management

For "prevention planning" concerning floods, the Department of Water Resources has developed flood management plans for the rivers. The department's management authority is restricted to the areas between the levees; management of floodplains and other areas subject to flooding are the responsibility of provinces, autonomous regions, municipalities, and local governments within their administrative areas. The Ministry of Finance and MWR are responsible for the organization and supervision of compensation, and local governments are responsible for implementation of the compensation. Local government is responsible for the maintenance of flood control works; but along the lower Yellow River, the maintenance of flood control works is the responsibility of the Yellow River Basin Conservancy Commission. The River Basin Flood Control Plans have been prepared by River Basin Commissions. Structural measures taken include dikes, dams, and diversions. Some simple, but effective, nonstructural measures have been implemented at the village level, such as warning messages of flood risk in mountainous areas during the rainy season delivered by broadcast, short message service (SMS) or text messaging, and drum alerts.

Current management of drought in the PRC is similar to flood management, with disaster response and "prevention planning." Several provinces, as well as six of the seven river basin commissions have prepared drought contingency plans. This planning includes both structural and nonstructural responses. "The structural measures differ based on area and natural conditions. Water storage projects consisting of dams and ponds generally are more common in the south; water diversion projects and electromechanical wells are found more often in the north. In the mountain areas, water storage projects are used; while the plains rely more heavily on water pumping projects."[80] Nonstructural measures used in prevention planning for drought include water allocation and sharing, water efficiency measures, and technical extension. These measures aim at reducing the cost and extent of interventions needed for disaster response.

E. Management of Other Water-Related Disasters

Coastal zone DRM is described in the Policies and Actions for Addressing Climate Change.[81] The PRC plans to enhance the management of coastal zones, raise protection

80 ADB. 2011. *Strategy for Drought Management.* Consultant's report. Manila (TA 7261-PRC).

81 PRC. 2012. *China's Policies and Actions for Addressing Climate Change.* http://en.theorychina.org/ chinatoday_2483/ whitebooks/201208/t20120809_230681.shtml

standards of coastal cities and major engineering projects, prevent excessive exploitation of groundwater, and take measures against land subsidence in coastal areas. Fresh water will be taken from rivers or reservoirs to dilute brackish water and deter seawater intrusion in estuaries. It will set up an emergency response system for marine disasters to control and prevent marine disasters in coastal regions. Climate and sea level changes in coastal areas will be evaluated and forecast, and the capability of marine and coastal ecosystems to cope with and adapt to climate change will be improved by promoting research and development for marine ecosystem protection and restoration, research results will be widely published, marine reserves established and management strengthened, coastal wetlands and marine environments restored, marine ecosystems demonstration areas set up, and coastal protection forest belts planted.

Current management of coastal disasters generally follows a command and control approach. Most coastal disaster management focuses on responding to disasters as they occur. Management of the coastal zone tends to be specific to a single issue such as fisheries or erosion with limited focus on disasters. Initial efforts have been made to implement integrated coastal zone management (ICZM). The leading agency for ICZM in the PRC is the Department of Sea Area Management, in the State Oceanic Administration, Ministry of Land and Natural Resources.

The Ministry of Land and Resources has effectively implemented research and identification of issues in land subsidence. Subsidence has a large number of causes, each falling under the jurisdiction of one or several different government bureaus.[82]

F. Integration of Water-Related Disaster Management with Ongoing People's Republic of China Reforms

The development of water-related DRM in the PRC is being aligned with the process of comprehensively deepening the reform of the entire country. This includes modernizing the governance structure for water-related DRM and providing capacity building for institutional strengthening, organic integration through refined laws, effective administration and encouragement of personal action, developing the market's role in fighting WRD, providing scientific and democratic governance in water-related DRM, and balancing ecological and human needs through comprehensive area-based zoning to establish ecological civilizations.[83] The overall aim in such management of WRD is to promote sustainable development and increase the long-term levels of security for individuals and businesses. Since this is a shared objective of these individuals, businesses, and of the government, as and when possible, water-related DRM is to become a shared task.

82 W. Qian and Y. Wang. 2012. Subsidence crisis: Taking responsibility. *News China.* February.: http://www.newschinamag.com/magazine/taking-responsibility

83 Ecological civilization is a key concept in the PRC's development, which brings together environmental protection, sustainable development, and social justice and fairness.

CHAPTER 6

Gaps and Opportunities in Water-Related Disaster Legislation and Management in the People's Republic of China

A. Legislation and Regulations

Overlapping and repetitive legislative content, waste of legislative resources, and conflicts and contradictions among laws are outcomes of the traditional approach to legislation—where each ministry develops its own regulatory process and supporting systems. Through implementation, the approach works against an integrated response, results in redundant infrastructure, and a waste of precious resources.[84] Agencies' staff are not likely to have the comprehensive understanding needed for efficient coordinated action should an event have multiple causes. There is a serious need for consolidation of legislation on disaster reduction.

The focus of the *Notice on the Approach to Emergency Preparedness* continues to be management of activities immediately following a disaster. It does not appear to provide directions on risk reduction through better physical, organizational, or financial planning, nor require revision of plans, other than the emergency management plan, in the recovery phase after a disaster. To date, the PRC fiscal approach to WRD appears to be primarily reactive, with the majority of central government expenditures allocated to disaster response.

The link between river basin planning and DRM needs to be built. Inputs to river basin planning by the basin community must be encouraged. Except for the Tarim River basin in far west of the PRC, river basin planning and management is currently largely a top-down process with some inputs by lower levels of government but lacking in any structure or process to involve the basin community, water users, and nongovernment organizations (NGOs).

The extension of emergency preparedness plans into planning by business and nongovernment agencies is a valuable addition to existing procedures. It may open the way for additional involvement of local volunteers for emergency response—as well as encouraging development of a strategic link with businesses.

A proactive approach to WRD management would reduce risk. This would involve (i) evaluation of long-term water resources and availability, as well as future water requirements, with subsequent assessment of water deficiency or flooding risk;

---

84 Government of the People's Republic of China, Ministry of Civil Affairs. 2012. *National Progress Report on the Implementation of the Hyogo Framework for Action (2011-2013) – Interim.* P 8/52 http://www.preventionweb.net/files/28446_chn_NationalHFAprogress_2011-13.pdf

(ii) monitoring of hydrometeorological variables and water resources availability, with subsequent early warning of potential water shortages or flooding; (iii) evaluation of drought and flooding impacts on societal and economic sectors; (iv) development of short-term (contingency) action plan and long-term preventive actions (a risk-based water resource plan); and (v) implementation of these plans (footnote 81).

The PRC is making efforts to recognize current and future risks, reduce and manage those risks, and be better able to adapt to change and recover from disasters. The main tasks planned by the PRC to further manage disaster risk and reduce the impacts of disaster based on their commitments under the Hyogo Framework for Action 2005–2015 include the following:

(i) Build a natural disaster risk database, and assess high-risk situations and key risk areas.
(ii) Improve the existing monitoring network, increase monitoring density, and launch a remote-sensing satellite for monitoring natural disasters. The PRC will improve disaster warning, forecasting, and decision-making systems; and promote integrated development and use of monitoring and early warning.
(iii) Implement plans for disaster prevention and reduction, strengthen the disaster management capabilities of large and medium-sized industrial enterprises, and improve main transportation routes and communication hubs for emergency use.
(iv) Implement emergency relief by the local authority, clearly dividing the work and establishing level-by-level control of disaster management.
(v) Specify a complete flood control and disaster prevention system for river basins to guarantee the safety of river valleys, including a comprehensive solution to both root causes and symptoms, and sound coordination. The basis of the system will be embankment construction and key water control projects on mainstreams and tributaries.
(vi) Pilot insurance schemes in agriculture and forestry, and evaluate disaster insurance and reinsurance.
(vii) Revise emergency response plans for urban and rural communities, and educate residents to prevent and deal with disasters. Improve urban and rural emergency facilities, and establish model communities.
(viii) Establish an Asian regional disaster research center to help improve the scientific and technical basis for strategies. Support a national network platform for disaster reduction knowledge.

The approach taken by the PRC is that of shared responsibility and increased resilience. This provides an opportunity for a cooperative nationwide effort that includes multiple agencies, communities, NGOs, and the private sector to make the PRC better able to withstand and recover from a disaster.

B. Flood and Drought Management

Limitations in emergency management, where they arise, are generally the result of unforeseen circumstances. The PRC is already planning to strengthen information and analytical support systems, including geographical information system and remote sensing capabilities, to reduce the occurrence of unforeseen circumstances. Recently, monitoring systems have been upgraded; and various systems have been developed to collect information in near real-time, some of these using remote sensing; but they have not yet been widely implemented yet.

Prevention planning to manage complex WRD risks, such as flooding, involves multiple agencies both in location (e.g., urban, rural, coastal, river basin) and in functional responsibility (e.g., water management, land use planning, transport, crop management, etc.). In March 2013, the State Council issued a comprehensive notice (*Improved Urban Flood Management and Drainage Facilities*) to all local government areas to review urban flooding, consider climate change impacts, and improve the construction and management of urban drainage systems to reduce the impacts of urban flooding.[85] However, it does not mention floodplain zoning (reducing risk through avoiding construction in areas prone to flooding) nor ecological values of the floodplain as a management issues, nor does it acknowledge the link required between urban flood management and river basin flood management plans. These linkages are important in relation to floodplain zoning, design standards for major waterway crossings, and in establishing tailwater conditions for urban drainage systems.

The river basin flood control plans have several limitations, including a heavy reliance on structural flood control measures, lack of watershed management provisions, exclusion of the management of tributaries and areas subject to waterlogging, and insufficient stakeholder involvement. The plans generally do not sufficiently incorporate other land use or sector plans and are often based on an analysis of limited management options.

The drought contingency plans have not yet been tested in implementation and the GHD Pty Ltd noted that how to "apply them to practical real conditions" will likely need guidance (footnote 78). A major issue in implementing drought management plans, and particularly for managing droughts which extend beyond a year, is the lack of clearly defined water rights. The lack of well-defined water rights and hierarchy of different user rights means the basis for water sharing is disputed. Water allocation currently relies on system design calculations, while history of water use may be very different for a variety of reasons. Work to strengthen water allocation and water rights systems is ongoing and is an important part of national actions to implement the Water Law and develop water management that is consistent with IWRM principles.

Areas of drought management plans that would benefit from further attention are (i) water use efficiency; (ii) crop varieties; (iii) efficiencies of scale, including cooperatives; (iv) integrated hydrological and meteorological monitoring, prediction, and modeling of water resources for agriculture; (v) improved seasonal forecasting and information systems; (vi) managing to sustainable water yields; (vii) water markets; (viii) financial support for farmers rather than drought mitigation; (ix) multiple structural approaches to water conservation ; and (x) the roles and responsibilities of different government agencies. Specific details are required for effective plans.

[85] Government of the People's Republic of China. 2013. *State Council Notice on Improved Urban Flood Management and Drainage Facilities.* SCS 23 [2013]. http://www.gov.cn/zwgk/2013-04/01/content_2367368.htm

C. Management of Other Water-Related Disasters

Management to reduce the occurrence and impact of coastal disasters (tropical cyclones, coastal flooding, coastal erosion, saltwater intrusion) in the PRC faces many challenges. The coastal zone of the PRC is divided among 12 provinces, and coordination and cooperation need to be improved across local government agencies. Initial efforts have been made to implement ICZM. The lead agency for ICZM in the PRC is the Department of Sea Area Management, in the State Oceanic Administration, Ministry of Land and Natural Resources. While assigning this responsibility to a long-standing agency and one which emphasizes the importance of the ocean in coastal zone management, the need for consideration of land management issues and land and sea interactions may prove a challenge. Analysis of the involvement of different agencies in land reclamation, coastal construction and dike building shows the important role of the MWR.[86] Projects to implement ICZM have however been implemented under other agencies, such as the MOA and the Fisheries Project Office.

Actions to manage the multiple causes of subsidence are problematic, as each causal factor falls within the responsibility of a particular agency (footnote 80). It may be that remote monitoring could be effectively used to evaluate and guide management responses implemented by provincial or local governments (footnote 26).

[86] M. Lau. 2004. Integrated Coastal Zone Management in the People's Republic of China: An Assessment of Structural Impacts on Decision-Making Processes. *FNU Working Paper*. 28. University of Hamburg, Germany. http://www.fnu.zmaw.de/fileadmin/fnu-files/publication/working-papers/OCM_LAUr_FNU.pdf; and M. Lau. 2006. Adaptation to Sea-Level Rise in the People's Republic of China: Assessing the Institutional Dimension of Alternative Organizational Frameworks. *Working Paper FNU-94*. University of Hamburg, Germany. http://www.fnu.zmaw.de/fileadmin/fnu-files/publication/working-papers/CLCH_fnu_LAU.pdf

CHAPTER 7

International Experience and Best Practices

A. International Experience

At the heart of water-related DRM in any country is the issue of water security. International experience shows that water security, can and must, be addressed on a river basin basis, through a strong and properly enforced water regulatory system, combined with a strategic water resource plan. Such a system has been under investigation in the PRC for the last 20 years, with assistance from a range of donors such as ADB, the European Union (EU), the World Bank, and bilaterally with member countries.

A key issue in successful implementation is clarity of responsibility: for a single and accountable lead organization. The EU has developed the role of "Competent Authority" to deliver EU Directives and to ensure accountability and delivery. Other countries, such as Australia and the United States, have different but equivalent "top agency" roles.

Large complex river basins can be managed, and significant improvements in equitable water sharing and in water quality can be made, given a strategic plan, clear river quantity and quality objectives, targeted investment, and a fixed timescale. All decisions can be modeled, and investment assessed and prioritized to maximum effect.

ADB flood and drought studies strongly recommend a risk management approach to disaster management (footnote 80). This approach, equivalent to an approach aiming at water security, is well described in ADB's Strategy for Drought Management. It is equally applicable to flood risk management.

> "The difference between drought management and drought disaster management is the management time-frame:
>
> Risk management is a proactive approach and is focused on the design of measures in advance of a drought that are intended to be put in place to prevent or mitigate the level of risk exposure and hence vulnerability to impacts. This approach seeks to build resilience in the systems to cope better in the future through structural and nonstructural measures on an ongoing basis. Disaster management is a reactive approach based on the implementation of measures and actions after a drought disaster is recognized. This approach applies to emergency situations and is likely to produce inefficient technical and economic solutions since actions are taken under stress without the time to adequately evaluate options. This tends to

> support dependence on emergency relief measures rather than resilience. The figure below outlines the difference between a reactive and proactive approach for drought management. The proactive approach is more complicated but supports a longer term outcome compared to the reactive approach. It leads to improved resilience, better planning, and more timely actions" (footnote 80, p. 9).

Internationally, it is generally accepted that following a disaster, the government and others (NGOs, commercial firms, and individuals) have a responsibility to provide assistance and aid recovery: the more sudden and severe the disaster, the greater the agreement to such action.

For prevention planning, perhaps because of its longer time horizon, there is less agreement on responsibility. For example, even whether individuals should be discouraged or prevented from placing developments in hazardous locations is still being debated in some countries. In the United States, there is current discussion as to whether federal flood insurance should be provided to individuals that choose to rebuild in coastal zones at high risk. To a degree, the appropriate balance in policy between government and individual responsibility is influenced by the level of development in the community and hence the individual's ability and resources for comprehensive assessment, planning, and decision making.

B. Some Specific Best Practices

1. Promoting Risk Reduction

Promotion of risk reduction measures, both structural and nonstructural, requires (i) the development of an appropriate system of incentives and disincentives, (ii) increased awareness regarding risks, (iii) accurate cost–benefit information of potential risk-reducing actions, and (iv) both political and public support. Political will is essential to provide the leadership required, create the policies and legislative framework, implement regulations (particularly zonation and building codes), identify and prioritize risk reduction measures, and allocate sufficient budgets. Opportunities for public inputs into the process are usually provided—either through public discussions or posting draft documents for public review. Public participation is considered essential to ensure buy-in and support for risk reduction measures.

2. Providing Incentives (Payment for Environmental Services or Eco-Compensation Mechanisms)

Payment for environmental services (PES) has been promoted as an incentive for resource conservation since the 1980s. PES is most commonly used for conserving water resources, but can apply to any environmental service, including carbon sequestration, biodiversity protection, or non-timber forest products. Costa Rica's adoption of PES as a national strategy for forest conservation has been regarded as highly successful. Viet Nam recently began pilot implementation of PES to sequester carbon and protect forest resources. In the PRC, the concept of PES has been modified and expanded; and is referred to as eco-compensation. Eco-compensation may provide a mechanism to strengthen proactive strategies for WRD management within river basin plans which aim to increase water security or as a component in ICZM plans. For example, eco-compensation could be used to fund watershed management and hence regulate water flows from upper catchments. Watershed management has been used as a response to flood disasters, but it is also applicable as part of a drought risk management strategy.[87]

ADB's previous work in eco-compensation has identified the need for the following: (i) a well-defined policy and legal basis, (ii) an analysis of the rights and responsibilities of the key stakeholders, (iii) a method to determine the eco-compensation criteria and amount, (iv) consideration of government-led vs. market-based eco-compensation, (v) financial mechanisms and arrangements to deal with eco-compensation funds, (vi) monitoring and evaluation to measure the performance, and (vii) implementing regulations.[88]

3. Establishing Links with Climate Change Adaptation

Linkages between WRD and adaptation strategies are being made by international organizations, NGOs, and multiple governments. Despite recognition of uncertainty remaining regarding the degree and scale of impacts of climate change on water resources, there is recognition of the need to incorporate available information from climate modeling and to follow adaptive management strategies.

4. Strengthening Linkages between Water-Related Disaster Management and Integrated Water Resources Management

WRD planning using IWRM principles adopts the river basin as the planning unit for land, water and other natural resources. Consideration of water availability includes groundwater as well as surface water, particularly given the importance of groundwater systems during drought periods. Plans have a clear definition of the outcomes that are desirable (i.e., they do not start from a proposed solution), apply rigorous, scientific analysis, comprehensive assessment of planning options, appraisals based on the triple bottom line of sustainable development (incorporating economic viability, social equity, and maintaining environmental quality), cost–benefit analysis and plans should be prepared with stakeholder involvement that extends outside the government sector. Flood management plans should follow the concepts of integrated flood management.[89]

5. Increasing Participatory Management

The roots of inadequacy in natural resources management, including water, lie not only in poor financing or technology or natural scarcity of water, but also include "poverty, inequality, and unequal power relationships, as well as flawed water management

[87] It should be noted that the PRC Conversion of Cropland to Forest and Grassland Program (also known as "Grain for Green" and the "Sloping Land Conversion Program") has elements which are similar to eco-compensation schemes. This program was launched right after the major Yangtze River flood of 1998.

[88] ADB. 2013. *Technical Assistance Completion Report: Preparing National Guidelines for Eco-Compensation in River Basins and a Framework for Soil Pollution Management.* Manila (TA 7217-PRC). http://www.adb.org/ sites/default/files/ projdocs/2013/42024-012-prc-tcr.pdf

[89] WMO. 2009. Integrated Flood Management Concept Paper http://www.apfm.info/publications/concept_paper_e.pdf

policies that exacerbate scarcity."[90] Providing opportunities for water user associations, NGOs, and community-based associations to become involved in strategic planning and implementation of disaster reduction is a commonly accepted approach to identifying vulnerabilities, reducing risks, improving monitoring, and quicker coordinated response during a WRD.

6. Increasing Access to Disaster Insurance

Increased access to disaster insurance is an effective action in both the urban and rural contexts. In the rural situation, insurance may encourage crop diversification. Crop insurance reduces the risk, hence increases choice and may encourage the farmer to opt for higher-value crops. In African countries, cheap crop insurance is available through mobile phone services and is having a significant effect in increased production value.[91] In the urban situation, WRD insurance will protect investments and reduce bad loans and has further benefit in relation to land use planning of discouraging development in areas of WRD risk.

7. Loss Estimation

Loss estimation is an important factor in risk assessment and in making decisions about managing risk.[92] The accuracy of loss estimates varies greatly both within and between countries, being subject to local capacity and knowledge of underlying processes. Loss estimates are reported to be better and more accurate for larger events, such as disasters, because of greater interest, larger number of estimates, and the aggregation of estimates.[93] (The accuracy of loss estimates from WRD assessed in this review is therefore likely to be reasonable.) However, it should be noted that loss estimates for flood events are generally better than those for drought, as drought is more gradual in its onset and tends to attract less attention, leading to less accurate damage estimates. In addition to loss estimates, the costs of disaster response are generally assessed and considered in determining disaster policy.

---

90 K. Watkins. 2006. *Human Development Report. Beyond Scarcity: Power, Poverty and the Global Water Crisis.* United Nations Development Programme.

91 R. V. Hill. 2010. *Agricultural Insurance in Sub-Saharan Africa: Can It Work?* Fourth African Agricultural Markets Program (AAMP) policy symposium, Agricultural Risks Management in Africa: Taking Stock of What Has and Hasn't Worked, Lilongwe, Malawi. http://fsg.afre.msu.edu/aamp/sept_2010/aamp_lilongwe-vargas_hill-agricultural_insurance.pdf

92 EM-DAT defines loss estimation as "The economic impact of a disaster which usually consists of direct (e.g., damage to infrastructure, crops, housing) and indirect consequences on the local economy (e.g., loss of revenues, unemployment, market destabilization). For each disaster, the registered figure corresponds to the damage value at the moment of the event, i.e., the figures are shown true to the year of the event."

93 M.W. Downton and R.A. Pielke, Jr. 2005. How Accurate are Disaster Loss Data? The Case of U.S. Flood Damage. *Natural Hazards.* (35). pp. 211–228.

CHAPTER 8

Conclusion and Final Recommendations

Water-related DRM presents a challenge for the PRC institutions given the multisector nature of the work. This challenge is being addressed both at the central level and more locally in the provinces.

Based on this review, there are six main areas in which multilateral financing may assist the PRC in strengthening its current management of WRDs. These are (i) data management, (ii) monitoring and forecasting, (iii) drought risk management, (iv) flood risk management, (v) sustainable urban development, and (vi) coastal management. Data management and forecasting are key areas within which to work to foster closer ties and to improve communication. There may be scope to review the PRC loss estimation methods and develop a model process for loss assessment for WRD in the PRC, as losses seem to be variably reported in the studied databases. To address gaps, Table 4 shows how to consolidate identified knowledge gaps and potential activities.

A detailed assessment of infrastructure needs would also be highly beneficial, as there are clearly many opportunities, such as those identified in the ADB report *Cost of Adaptation to Rising Coastal Water Levels for the People's Republic of China, Japan, and the Republic of Korea.*[94] For flood risk management, there are large infrastructure needs in both urban and rural areas, including both new and upgraded construction. For drought management, infrastructure to increase irrigation efficiency and flexibility of water management during droughts should be given high priority.

The preparation of the upcoming Thirteenth Five-Year Plan presents the PRC with an opportunity to address policy gaps, strengthen institutional coordination, and implement new activities to prevent WRDs as well as reduce their impact through DRM. The PRC may wish to consider the following:

(i) Consolidate disaster management legislation and integrate with natural resource planning and management legislation.
(ii) Improve coordination and cooperation, and clarify roles and responsibilities between departments, agencies, ministries, and levels of government. Designate a single and accountable lead organization.

[94] ADB. 2013. *Cost of Adaptation to Rising Coastal Water Levels for the People's Republic of China, Japan, and the Republic of Korea.* Manila. http://www.adb.org/sites/default/files/pub/2013/cost-adaptation-rising-coastal-water-levels-prc-jap-kor.pdf

(iii) Address identified knowledge gaps; and clarify linkages between flood management, river basin management, coastal zone management, and WRD (including climate change impacts).

(iv) Scale up eco-compensation programs for watersheds, and broaden the participation of commercial entities and communities.

(v) Improve calculations of water availability and demand, and clearly specify water use rights, regulations for water sharing, trading, and water pricing.

(vi) Adopt a risk management approach to disaster management.

(vii) Improve loss estimations.

(viii) Promote disaster insurance, provide incentives for purchasing, and expand access.

Table 4: Activities Addressing Identified Knowledge Gaps

Knowledge Gap	Activity
Disaster management legislation should be consolidated and integrated with natural resource planning and management legislation.	Consolidate water-related disaster (WRD) legislation and link to water, urban planning, and coastal management legislation.
Strengthen national disaster database and information tools.	Strengthen the national disaster management database. Make greater use of geographic information system (GIS), remote sensing, and other information tools. Build strong information networks.
Early warning systems exist but they need improvement through better and timelier data, and improved tools.	Construct an improved early warning system for WRD with well-designed and nationally consistent messages.
Building standards exist, but they are not comprehensive and need updating to accommodate climate change impacts.	Revise building standards and strengthen their application.
Vocational courses for building and urban planning professionals do not include natural resources management principles.	Develop vocational training courses for professionals in urban planning and building industry sectors which include natural resources management principles and revised building standards.
The public does not have clear information on WRD hazards when purchasing land or planning developments.	WRD hazard and risk data prepared and provided to urban planning agencies in forms suitable for businesses and community members interested in construction, land purchase, or land sale. This may include drafting national and/or provincial agreements and draft legislation to formalize the process.
Disaster management should be integrated with urban planning processes.	Draft a model regulation requiring flood mapping in areas identified in provincial WRD risk management plans as being at high risk, and to require authorities and individuals to consider the appropriateness of rebuilding in the same location or rebuilding to a more resilient standard to reduce future risks following WRD impacts.

continued on next page

Table 4: continued

Knowledge Gap	Activity
Community leaders need to recognize and understand the risks WRD pose to their own and their community's interests.	River basin commissions lead in WRD risk reduction, coordinating this with provinces in the river basin, and encouraging community outreach and involvement. Departments support activities in WRD stakeholder and community engagement, resilience-building and capability development, disaster risk management, and disaster response and recovery.
Linking integrated river basin management (IRBM) and WRD risk management	Strengthen river basin commission (RBC) flood management plans by extending to tributaries, greater consideration of nonstructural measures, and extending stakeholder involvement. Assist provinces to update WRD management plans. Strengthen RBC drought management plans by linking with provincial water system operational plans and drought disaster management plans.
Linking integrated coastal zone management (ICZM) and WRD risk management	Pilot updating a provincial coastal disaster risk management plan through links with ICZM.
Linking IRBM, ICZM, and WRD risk management	Pilot updating a provincial coastal disaster risk management plan through links with an IRBM plan and an ICZM plan.
WRD information and WRD insurance for urban areas	Prepare comprehensive WRD hazard information and investigate options for a WRD insurance scheme for a pilot urban area.[a]
WRD information and WRD insurance for rural areas	Prepare comprehensive WRD hazard information and investigate options for a WRD insurance scheme for a pilot rural area, building on experience from the rural house insurance program and the trial agriculture insurance schemes.

[a] Such activity should incorporate lessons learned from G. Walker, T. Lin, and Y. Kobayashi. 2009. Is Flood Insurance Feasible? Experiences from the People's Republic of China. *ADB Economics Working Paper Series.* No. 5. Manila: Asian Development Bank.

APPENDIX 1

Glossary

Avalanche: A quantity of snow or ice that slides down a mountainside under the force of gravity. It occurs if the load on the upper snow layers exceeds the bonding forces of the entire mass of snow. It often gathers material that is underneath the snowpack such as soil, rock, etc. (debris avalanche). Any kind of rapid snow or ice movement.

Blizzard or snowstorm: A severe snowstorm characterized by strong winds, blowing snow, and low or falling temperatures is called a blizzard. A storm with large amounts of snowfall is a snowstorm.

Climatological disasters: Events caused by long-lived or meso- to macro-scale processes (in the spectrum from intra-seasonal to multi-decadal climate variability).

Cold wave: A prolonged period of excessively cold weather and/or the sudden invasion of very cold air over a large area. Along with frost it can cause damage to agriculture, infrastructure, and property due to low temperatures.

Disaster: Situation or event, which overwhelms local capacity, necessitating a request to national or international level for external assistance (definition considered in EM-DAT). An unforeseen and often sudden event that causes great damage, destruction and human suffering. Though often caused by nature, disasters can have human origins. Wars and civil disturbances that destroy homelands and displace people are included among the causes of disasters. Other causes can be building collapse, blizzard, drought, epidemic, earthquake, explosion, fire, flood, hazardous material or transportation incident (such as a chemical spill), hurricane, nuclear incident, tornado, or volcano.

Disaster event: A disaster meeting the EM-DAT criteria and which is recorded in EM-DAT. A disaster event can affect one country or several. In the case of the latter, the disaster event will result in several country-level disasters being entered into the database. A disaster event will always have a unique disaster reference number (DisNo) identifier.

Drought: An extended period of time characterized by a deficiency in a region's water supply that is the result of constantly below average precipitation. A drought can lead to losses to agriculture, affect inland navigation and hydropower plants, and cause a lack of drinking water and famine.

Emergency: Sudden and usually unforeseen event that calls for immediate measures to minimize its adverse consequences.

Estimated damage: The economic impact of a disaster usually consists of direct (e.g., damage to infrastructure, crops, housing) and indirect (e.g., loss of revenues, unemployment, market destabilization) consequences on the local economy. In EM-DAT estimated damage are given in $ ('000). For each disaster, the registered figure corresponds to the damage value at the moment of the event, i.e., the figures are shown true to the year of the event.

Extreme winter conditions (winter storm): Damage caused by snow and ice to buildings, infrastructure, traffic (especially navigation) inflicted by snow and ice in form of snow pressure, freezing rain, frozen waterways, etc.

Flash flood: A sudden flooding with short duration. In sloped terrain, the water flows rapidly with a high destruction potential. In flat terrain, the rainwater cannot infiltrate into the ground or runoff (due to small slope) as quickly as it falls. Flash floods typically are associated with thunderstorms. A flash flood can occur at virtually any place.

Flood: Significant rise of water level in a stream, lake, reservoir, or coastal region.

General flood: Gradually rising inland floods (rivers, lakes, groundwater) due to high total depth of rainfall or snowmelt. It is caused when a body of water (river, lake) overflows its normal confines due to rising water levels. The term general flood additionally comprises the accumulation of water on the surface due to long-lasting rainfall (water logging) and the rise of the groundwater table above surface. Furthermore, inundation by melting snow and ice, backwater effects, and special causes such as the outburst of a glacial lake or the breaching of a dam are subsumed under the term general flood. General floods can be expected at certain locations (e.g., along rivers) with a significantly higher probability than at others.

Geophysical disasters: Events originating from solid earth.

Hailstorm: A type of storm that is characterized by hail as the dominant part of its precipitation. The size of the hailstones can vary between pea size (6 millimeters) and softball size (112 millimeters) and therefore cause considerable damage.

Hazard: Threatening event, or probability of occurrence of a potentially damaging phenomenon within a given time period and area.

Heat wave: A heat wave is a prolonged period of excessively hot and sometimes also humid weather relative to normal climate patterns of a certain region.

Hydrological disasters: Events caused by deviations in the normal water cycle and/or overflow of bodies of water caused by wind setup.

Landslide: The movement of soil or rock controlled by gravity and the speed of the movement usually ranges between slow and rapid, but not very slow. It can be superficial or deep, but the materials have to make up a mass that is a portion of the slope or the slope itself. The movement has to be downward and outward with a free face.

Lightning hazards or losses caused by lightning strike: Lightning is an atmospheric discharge of electricity, which typically occurs during thunderstorms, and sometimes during volcanic eruptions or dust storms.

Meteorological disasters: Events caused by short-lived and small to meso-scale atmospheric processes (in the spectrum from minutes to days).

Orographic storm: A rain or snow event that is significantly enhanced by uplift of an air mass over a mountain barrier.

Risk: Expected losses (of lives, persons injured, property damaged, and economic activity disrupted) due to a particular hazard for a given area and reference period. Based on mathematical calculations, risk is the product of hazard and vulnerability.

Rockfall: Quantities of rock or stone falling freely from a cliff face caused by undercutting, weathering, or permafrost degradation.

Sandstorm or dust storm: Typically occurs in arid or semiarid regions if high wind speeds cause the transport of small particles, such as sand or fine clastic sediment, by saltation and/or suspension (e.g., in deserts).

Severe storm: A severe storm or thunderstorm is the result of convection and condensation in the lower atmosphere and the accompanying formation of a cumulonimbus cloud. A severe storm usually comes along with high winds, heavy precipitation (rain, sleet, or hail), thunder, and lightning.

Storm surge: The rise of the water level in the sea, an estuary, or lake as result of strong wind driving the seawater toward the coast. This so-called wind setup is superimposed on the normal astronomical tide. During a storm surge, the mean water level can increase to 5 meters or more. The areas usually threatened by storm surges are coastal lowlands.

Subsidence: The motion of the Earth's surface as it shifts downward relative to a datum (e.g., the sea level). Subsidence (dry) can be the result of geological faulting, isostatic rebound, human impact (e.g., mining, extraction of natural gas), etc. Subsidence (wet) can also be the result of karst, changes in soil, water saturation, permafrost degradation (thermokarst), etc.

Tailwater: The waters located immediately downstream from a hydraulic structure.

Tornado: A rotating column of air (vortex) that emerges out of the base of a cumulonimbus cloud and has contact to the Earth's surface. Typically, it forms during a severe convective storm in so-called supercells and is often visible as a funnel-shaped cloud. Tornadoes are usually short-lived, lasting on average to no more than 10 minutes. It can generate wind speeds above 400 kilometers per hour, and is considered the most destructive weather phenomenon. The intensity of tornadoes is assessed using the Enhanced Fujita Scale. Other names for this weather phenomenon are twister and waterspout (over open water).

Total affected: In EM-DAT, people that have been injured, affected, and left homeless after a disaster are included in this category.

Tsunami: A series of waves caused by a rapid displacement of a body of water (ocean, lake). The waves are characterized by a very long wavelength and their amplitude is much smaller offshore. The impact in coastal areas can be very destructive as the waves advance inland and can extend over thousands of kilometers. Triggers of a tsunami can be earthquakes, volcanic eruptions, mass movements, meteorite impacts, or underwater explosions.

Typhoon: Large-scale closed circulation system in the atmosphere above the western Pacific with low barometric pressure and strong winds that rotate clockwise in the southern hemisphere and counterclockwise in the northern hemisphere. Has a maximum wind speed of 64 knots or more.

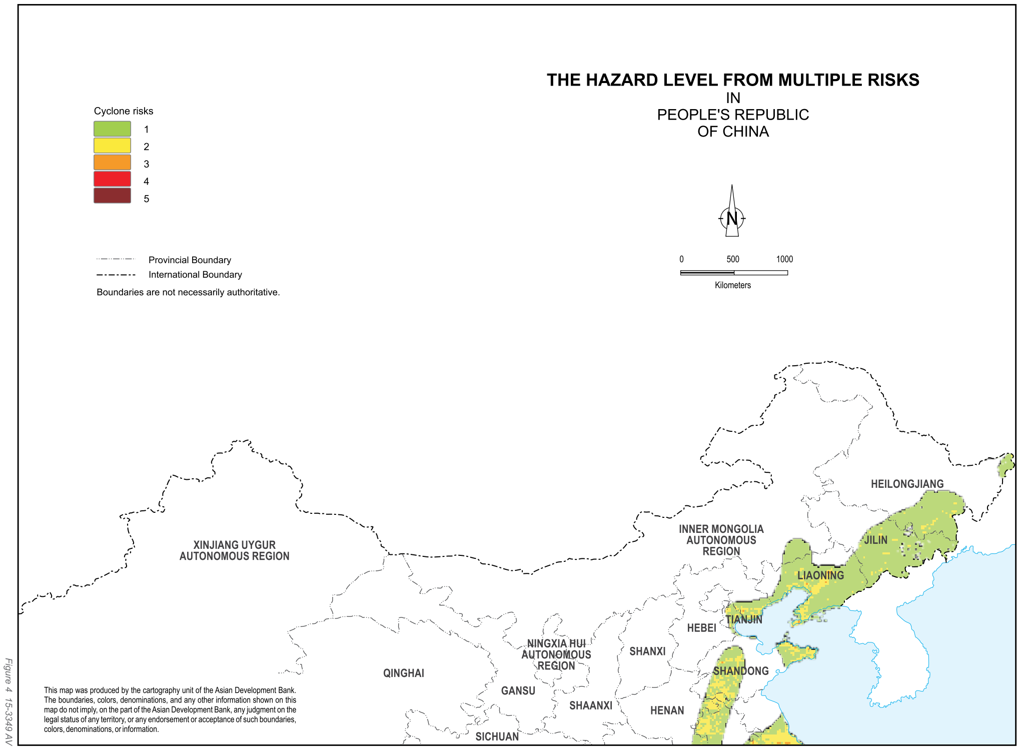
Vulnerability: Degree of loss (from 0% to 100%) resulting from a potential damaging phenomenon.

Winter storm (extreme winter conditions): Damage caused by snow and ice. Winter damage refers to damage to buildings, infrastructure, traffic (especially navigation) inflicted by snow and ice in the form of snow pressure, freezing rain, frozen waterways, etc.

APPENDIX 2

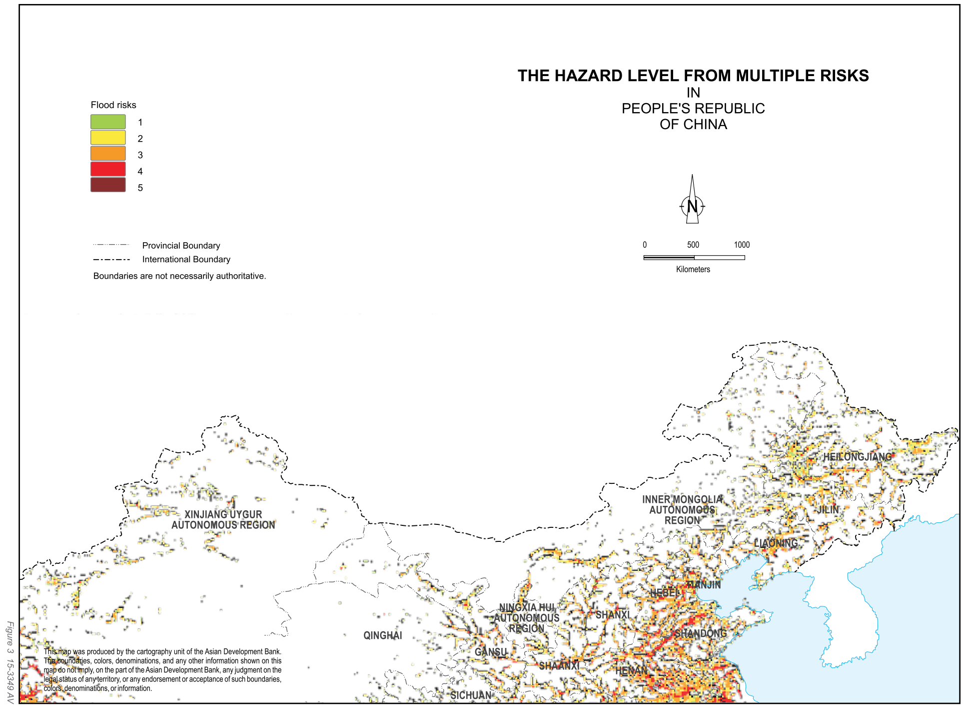
Spatial Distribution of Hazards

Figure A2.1. Tropical Cyclone Risk



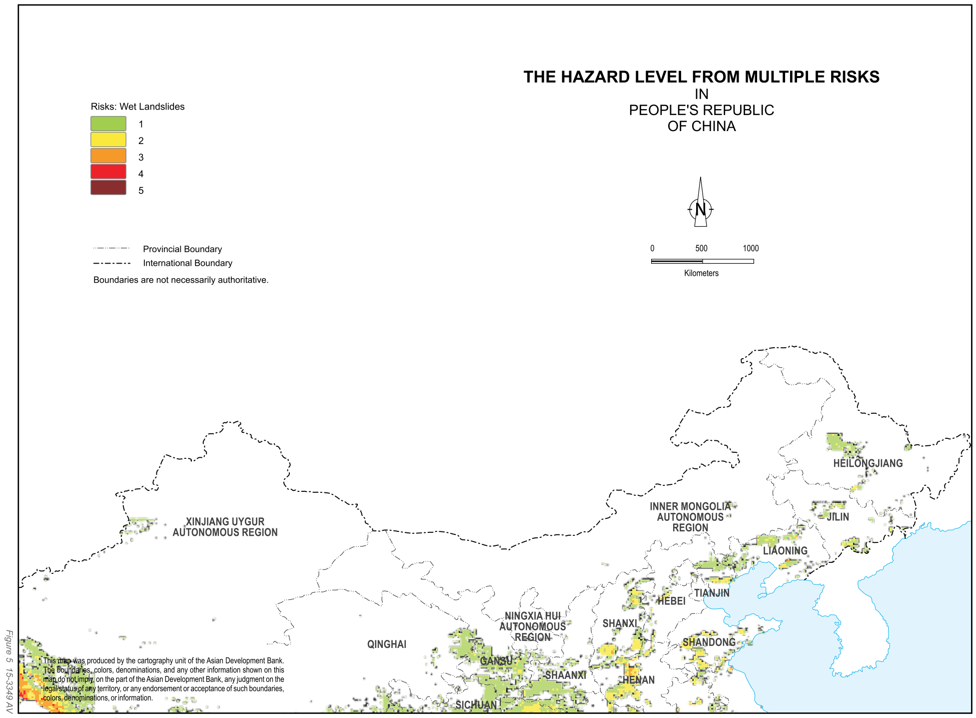
Source: Mapping by H Milner, data from the Global Risk Data Platform (GRID), boundaries are approximate.

Figure A2.2. Flood Risks



Source: Mapping by H Milner, data from the Global Risk Data Platform (GRID), boundaries are approximate.

Figure A.2.3. Landslide Risk



Source: Mapping by H Milner, data from the Global Risk Data Platform (GRID), boundaries are approximate.

APPENDIX 3

Roles and Responsibilities of the Flood Control and Drought Relief Office

Table A3. Roles and Responsibilities of the Flood Control and Drought Relief Office and the Associated Agency Major Roles and Responsibilities

No.	Agency Name	Roles and Responsibilities
1	Flood Control and Drought Relief Office	Carry out state guidelines, policy and regulations in relation to drought relief; organize prepare and implement preparedness scheme for drought relief; collect data on the latest rainfall, water, drought, disaster, and meteorological situations; understand short-term and long-term analyses of water and meteorology; organize drought relief supervision; responsible for storage and management of drought relief materials; drought relief fund planning; collection of data on drought disaster conditions; develop and manage drought communication and warning system; carry out drought relief education and training; promote advanced techniques and new products.
2	Propaganda Agency	Responsible for guidance of drought relief communications: timely coordinating of press releases, media news reporting by associated agencies.
3	Development and Reform Commission	Provide guidance to drought relief planning and development; responsible for risk mitigation and strengthening of drought relief facilities and important engineering; coordination and supervision of drought relief plan.
4	Public Security Agency	Maintain social order; crack down on criminal activities according to the laws, such as spreading rumors, theft of drought relief materials, deliberate destruction of drought relief facilities; assist relevant departments in properly dealing with mass security events triggered by drought relief; assist in organizing safe evacuation of the population from dangerous areas.
5	Civil Affairs Agency	Organize and coordinate drought disaster relief; provide the latest disaster information to headquarters; organize and coordinate the rescue of rescuers and victims; manage and supervise disaster relief materials and fund; organize and distribute donations.
6	Finance Agency	Responsible for drought relief fund budget, allocation and supervision.
7	Land and Resources Agency	Organize monitoring and prevent geologic disaster.
8	Construction Agency	Assist in the guidance of urban drought relief planning works.
9	Railway Agency	Organize the transportation of personnel, materials, and equipment.

continued on next page

Table: continued

No.	Agency Name	Roles and Responsibilities
10	Communication Agency	Assist local agencies in charge of communication to organize the transportation of personnel, materials, and equipment.
11	Industry and Information Technology Agency	Responsible for drought relief communication works, and regulation of emergency communication facilities when necessary.
12	Water Resources Agency	Responsible for organization, coordination, supervision, and guidance of daily drought relief works; management of drought relief projects; organize and direct construction and management of drought relief projects; supervision and management of drought situation and safety of drought relief projects.
13	Agricultural Agency	Collect, analyze, and report agricultural drought and disaster conditions in a timely manner; provide guidance in agricultural drought relief, disaster relief and production recovery; advise on adjustments to crops, water-saving techniques and prevention of endemic diseases among livestock; responsible for special subsidy fund allocation and management; responsible for reservation, allocation and management of emergency seed, forage grass, and animal epidemic prevention materials.
14	Commerce Agency	Strengthen the monitoring and supervision of market, supply and demand of important goods; coordinating the organization and supply of drought relief materials and post-disaster construction materials.
15	Sanitation and Quarantine Agency	Responsible for disease prevention and medical rescue; reporting epidemic conditions and prevention information to the headquarters; organize local health department and medical personnel to carry out disease prevention and treatment, and control of occurrence and spread of the epidemic.
16	Civil Aviation Agency	Responsible for the transport of drought relief personnel, medical personnel, materials and equipment; providing necessary emergency air transport and people in emergency.
17	Radio and TV Broadcast Agency	Responsible for timely and accurate directing of communications about drought on TV and radio at all levels; reporting drought situation, disaster situation and drought relief works that are approved by the headquarters.
18	Administration Agency of Work Safety	Supervision and instruction regarding safe production during flood periods; enhancing the supervision and examination of hydropower stations, mines, tailing dams, and other important structures during flooding.
19	Meteorological Agency	Responsible for monitoring and forecasting of weather; analysis and forecasting of drought conditions; issuing updated forecasts of important weather and disaster events; providing meteorological information to the flood control and drought relief headquarters and related agencies.
20	Army, Armed Police and People's Armed Forces Department	Responsible for participating in the rescue and relief work of major structures and emergencies; assisting the local public security agency to maintain order and social security in disaster areas; assisting the local government to the masses in the dangerous areas.

Source: GHD. 2011. *Strategy for Drought Management.* Technical Assistance 7261-People's Republic of China Final Report. Manila: Asian Development Bank.

References

Asian Development Bank (ADB). 2011. *Technical Assistance Report to the People's Republic of China: Strategy for Drought Management.* Manila (TA 7261-PRC).

ADB. 2013. *Cost of Adaptation to Rising Coastal Water Levels for the People's Republic of China, Japan, and the Republic of Korea.* http://www.adb.org/sites/default/files/pub/2013/cost-adaptation-rising-coastal-water-levels-prc-jap-kor.pdf

ADB. 2013. *Food Security in Asia and the Pacific.* http://www.adb.org/sites/default/files/publication/30349/food-security-asia-pacific.pdf http://www.cropwatch.com.cn/htm/en/index.shtml

ADB. 2013. *Key Indicators.* http://www.adb.org/sites/default/files/ki/ 2013/pdf/PRC.pdf; and the World Population Statistics for forecast (2013, 2030), http://www.worldpopulationstatistics.com/china-population-2013/

ADB. 2013. *Technical Assistance Completion Report: Preparing National Guidelines for Eco-Compensation in River Basins and a Framework for Soil Pollution Management.* Manila (TA 7217-PRC). http://www.adb.org/ sites/default/files/projdocs/2013/42024-012-prc-tcr.pdf

Agricultural Production Information. http://faostat.fao.org/site/339/default.aspx

D.M. Anderson and S. McCarthy. 2012. *Expert Workshop on Red Tides and Harmful Algal Blooms: Impacts on Desalination Operations.* Middle East Desalination Research Center, National Center of Excellence, Oman. 8–9 February 2012. http://www.medrc.org/download/Habs_and_desaliantion_workshop_report_ final.pdf

L. Bengtsson et al. 2007. How may Tropical Cyclones change in a Warmer Climate? *Tellus* A. 59. pp. 539–561.

C.E. Boyle. 2007. *A China Environmental Health Project Research Brief: Water-Borne Illness in China.* Wilson Center, China Environment Forum. Washington DC; and http://www.wilsoncenter.org/sites/default/ files/waterborne_Aug07.pdf

British Embassy. 2014. *China in Numbers.* United Kingdom. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/320305/Chinanumbers_-_June_2014.pdf

E.J. Carlton et al. 2012. Regional Disparities in the Burden of Disease Attributable to Unsafe Water and Poor Sanitation in China. *Bulletin, World Health Organization.* 90. pp. 578–587. doi:10.2471/BLT.11.098343. http://www.who.int/bulletin/volumes/90/8/11-098343.pdf

L. Clark. 2012. Chinese Survey Reveals Heavy Coastal Pollution, Red Tides, and Water Shortages. *Wired UK, Science.* http://www.wired.co.uk/news/archive/2012-11/07/chinese-water-pollution

S. Dasgupta et al. 2009. *Sea-Level Rise and Storm Surges: A Comparative Analysis of Impacts in Developing Countries.* Washington DC: World Bank. pp. 1-41.

F. Ding et al. 2011. *Numerical Study on Seawater Intrusion into Groundwater in Liaodong Bay Coastal Plain, China.* 1. pp. 725–729. International Symposium on Water Resource and Environmental Protection (ISWREP), 20–22 May 2011.

M.W. Downton and R.A. Pielke, Jr. 2005. How Accurate are Disaster Loss Data? The Case of U.S. Flood Damage. *Natural Hazards.* 35. pp. 211–228.

M. Eineder and Y. Zhang. 2012. *Mapping Land Subsidence with Multi-Frequency Time Series SAR Images.* Dragon 2 Final Results and Dragon 3 KO Symposium. 25–29 June 2012.

K.A. Emanuel et al. 2008. Hurricanes and Global Warming: Results from Downscaling IPCC AR4 Simulations. *Bulletin of the American Meteorological Society.* 89. pp. 347–367.

Extreme Temperatures around the World. http://www.mherrera.org/temp.htm

M. Falkenmark et al. 2009. Present and Future Water Requirements for Feeding Humanity. *Food Security.* 1. pp. 59–69.

FAO. 2012. *The State of World Fisheries and Aquaculture.* http://www.fao.org/docrep/016/i2727e/i2727e.pdf

M. Godfrey. 2014. *China Government wants Solution to Aquaculture Insurance Conundrums.* http://www.seafoodsource.com/news/aquaculture/26415-china-government-wants-solution-to-aquaculture-insurance-conundrums

A. Goudie. 2009. Dust Storms: Recent Developments. *Journal of Environmental Management.* 90. pp. 89–94.

S. Hanson et al. 2011. A Global Ranking of Port Cities with High Exposure to Climate Extremes. *Climatic Change.* 104. pp. 89–111.

L.J. Henderson. 2004. Emergency and Disaster: Pervasive Risk and Public Bureaucracy in Developing Nations. *Public Organization Review.* 2004. 4(2). pp. 103–119.

R. V. Hill. 2010. *Agricultural insurance in Sub-Saharan Africa: Can It Work?* Fourth African Agricultural Markets Program (AAMP) policy symposium, Agricultural Risks Management in Africa: Taking Stock of What Has and Hasn't Worked, Lilongwe, Malawi. September 6-10, 2010 http://fsg.afre.msu.edu/aamp/sept_2010/aamp_lilongwe-vargas_hill-agricultural_insurance.pdf

http://preview.grid.unep.ch/index.php

http://www.asifma.org/uploadedFiles/Resources/PRC-12th-FYP(1).pdf

http://www.avoid.uk.net/

http://www.emdat.be/glossary/9#letterd

http://www.stats.gov.cn/english/StatisticalCommuniqu/201302/t20130222_61456.html

J. Huggel et al. 2012. Is Climate Change Responsible for Changing Landslide Activity in High Mountains? *Earth Surf. Process. Landforms.* 37. pp. 77–91. doi: 10.1002/esp.2223.

IPCC. 2007. *Climate Change 2007: Impacts, Adaptation and Vulnerability.* Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, United Kingdom.

IPCC. 2014. *Impacts, Adaptation and Vulnerability.* Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK; and http://ipcc-wg2.gov/AR5/images/uploads/WG2AR5_SPM_FINAL.pdf

T. Jiang et al. 2007. Temporal and Spatial Trends of Precipitation and River Flow in the Yangtze River Basin, 1961–2000. *Geomorphology.* 85. pp. 143–154.

Z.H. Jiang et al. 2011. Extreme Climate Events in China: IPCC-AR4 Model Evaluation and Projection. *Climatic Change.* Published online. http://link.springer.com/article/10.1007%2Fs10584-011-0090-0#

Z.W. Kundzewicz et al. 2012. Flood Risk and Climate Change: Global and Regional Perspectives. *Hydrological Sciences Journal.* 59 (1). pp. 1–28.

M. Lau. 2004. Integrated Coastal Zone Management in the People's Republic of China: An Assessment of Structural Impacts on Decision-Making Processes. *FNU Working Paper.* 28. University of Hamburg, Germany. http://www.fnu.zmaw.de/fileadmin/fnu-files/publication/working-papers/OCM_LAUr_FNU.pdf

M. Lau. 2006. Adaptation to Sea-level Rise in the People's Republic of China: Assessing the Institutional Dimension of Alternative Organizational Frameworks. *Working Paper FNU-94.* University of Hamburg, Germany. http://www.fnu.zmaw.de/fileadmin/fnu-files/publication/working-papers/CLCH_fnu_LAU.pdf

M. Lei et al. 2002. New Advances in Karst Collapse Research in China. *Environmental Geology.* 42(5). pp. 462–468.

Y. Liming et al. 2013. Climate Change Impact on China Food Security in 2050. *Agronomy for Sustainable Development.* April. 33 (2). pp. 363–374. http://link.springer.com/article/10.1007%2Fs13593-012-0102-0

C. Liu et al. 2013. Susceptibility Evaluation and Mapping of China's Landslides Based on Multi-Source Data. *Natural Hazards.* doi 10.1007/s11069-013-0759-y.

C. Liua et al. 2012. Susceptibility Evaluation and Mapping of China's Landslide Disaster Based on Multi-Temporal Ground and Remote Sensing Satellite Data. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences.* XXXIX-B8. XXII ISPRS Congress, 25 August–1 September 2012. Melbourne, Australia.

R.M. Llamas and E. Custodio, eds. 2002. *Intensive Use of Groundwater: Challenges and Opportunities.* Taylor and Francis. p. 126.

D.B. Lobell et al. 2008. Prioritizing Climate Change Adaptation Needs for Food Security in 2030. *Science*. 319. pp. 607–610.

R. Mendelsohn et al. 2012. The Impact of Climate Change on Global Tropical Cyclone Damages. *Nature Climate Change.* 2. pp. 205–209.

Meteorological Office, UK. 2012. *Climate: Observations, Projections and Impacts, Fact Sheet. Case Study.* http://www.metoffice.gov.uk/media/pdf/7/9/COP18_Factsheet_-_China.pdf

Ministry of Civil Affairs. 2012. *National Progress Report on the Implementation of the Hyogo Framework for Action (2011–2013) – Interim.* p 8/52 http://www.preventionweb.net/files/28446_chn_NationalHFAprogress_2011-13.pdf

F. Nadim et al. 2006. Global Landslide and Avalanche Hotspots. *Landslides.* 3(2). pp. 159–173.

K. Oouchi et al. 2006. Tropical Cyclone Climatology in a Global-Warming Climate as Simulated in a 20 km-Mesh Global Atmospheric Model: Frequency and Wind Intensity Analyses. *Journal of the Meteorological Society of Japan.* 84. pp. 259–276.

J. Peng. 2011. WaterWorld. *Market Report: Developing Desalination in China.* http://www.waterworld.com/articles/wwi/print/volume-25/issue-6/regional-spotlight-asia-pacific/market-report-developing-desalination.html

People's Republic of China (PRC). 2012. *China's Policies and Actions for Addressing Climate Change.* http://en.theorychina.org/ chinatoday_2483/whitebooks/201208/t20120809_230681.shtml

PRC Ministry of Civil Affairs. 2012. *National Progress Report on the Implementation of the Hyogo Framework for Action (2011–2013) –Interim.* Beijing. http://www.preventionweb.net/english/hyogo/progress/reports/ v.php?id=28446&pid:223

PRC State Council. 2013. *State Council Notice on the Approach to Emergency Preparedness.* SCS [2013]. No. 101. http://www.gov.cn/zwgk/2013-11/08/content_2524119.htm#

PRC. 2013. *State Council Notice on Improved Urban Flood Management and Drainage Facilities.* SCS 23 [2013]. http://www.gov.cn/zwgk/2013-04/01/content_2367368.htm

PRC Ministry of Civil Affairs. 2015. *Official Statement from Ministry of Civil Affairs at Third World Conference on Disaster Reduction.* Sendai, Japan, 14-18 March 2015.

W. Qian and Y. Wang. 2012. Subsidence Crisis: Taking Responsibility. *News China.* February 2012. http://www.newschinamag.com/magazine/taking-responsibility

C. Ringler et al. 2010. Yellow River Basin: Living with Scarcity. *Water International.* 35. pp. 681–701.

B. Su, M. Gemmer, and T. Jiang. 2008. Spatial and Temporal Variation of Extreme Precipitation over the Yangtze River Basin. *Quaternary International.* 186. pp. 22–31.

M. Stowasser et al. 2007. Tropical Cyclone Changes in the Western North Pacific in a Global Warming Scenario. *Journal of Climate.* 20. pp. 2,378–2,396.

J.Y. Tu et al. 2009. *Journal of Climate.* 22: pp. 3,617–3,628.

C.J. Vörösmarty et al. 2010. Global Threats to Human Water Security and River Biodiversity. *Nature.* 467. pp. 555–561.

X. Wang et al. 2004. Modern Dust Storms in China: An Overview. *Journal of Arid Environments.* 58. pp. 559–574.

M. Wang. 2010. *Natural Disaster Insurance in China: Practice and Lessons Learned.* Global Risk Forum, Davos, 11 June 2010. http://www.slideshare.net/GRFDavos/idrc2010mingwangpptx

M. Wang et al. 2011. *Agriculture Insurance in China: History, Experience, and Lessons Learned.* Int. J. Disaster Risk Sci. 2 (2). pp. 10–22. doi:10.1007/s13753-011-0007-6.

M. Wang et al. 2012. Are People Willing to Buy Natural Disaster Insurance in China? Risk Awareness, Insurance Acceptance, and Willingness to Pay. *Risk Analysis.* 32(10). pp. 1,717–1,740.

W. Wu et al. 2011. Scenario-Based Assessment of Future Food Security. *Journal of Geographical Sciences.* 21. pp. 3–17.

R. Warren et al. 2010. *The Economics and Climate, Change Impacts of Various Greenhouse Gas Missions Pathways: A Comparison between Baseline and Policy Emissions Scenarios.* AVOID Report. AV/ WS1/D3/R01. http://www.metoffice.gov.uk/avoid/files/resources-researchers/AVOID_WS1_D3_01_20100122.pdf

K. Watkins. 2006. *Human Development Report. Beyond Scarcity: Power, Poverty and the Global Water Crisis.* United Nations Development Programme.

WMO. 2009. *Integrated Flood Management Concept Paper.* http://www.apfm.info/publications/concept_paper_e.pdf

J. Xie et al. 2013. *Addressing China's Water Scarcity, Recommendations for Selected Water Resource Management Issues.* Table 2.1. World Bank. http://elibrary.worldbank.org/doi/abs/10.1596/978-0-8213-7645-4

P. Xue et al. 2009. Saltwater Intrusion into the Changjiang River: A Model-Guided Mechanism Study. *Journal of Geophysical Research.* 114. C02006, doi:10.1029/2008JC004831.

Y. Yang et al. 2012. The variability of Sand-Dust Storm Frequency in North-East Asia from 1980 to 2011. *Acta. Meteor. Sinica*. 27(1). pp. 119-127. doi: 10.1007/s13351-013-0112-0.

L. Yuanyuan. 2013. *Long-Term Strategy for Water Resources Management in the PRC.* GIWP, Ministry of Water Resources, PRC.

Y. Yin et al. 2006. *Urbanization and Land Subsidence in China.* IAEG2006 Paper number 31. http://iaeg2006.geolsoc.org.uk/cd/PAPERS/IAEG_031.pdf

Y. Yin. 2011. Recent Catastrophic Landslides and Mitigation in China. *Journal of Rock Mechanics and Geotechnical Engineering.* 3 (1). pp. 10–18.

L. Yong et al. 2006. *The Current State of Aquaculture Insurance in China.* In FAO. 2006. *Review of the Current State of World Aquaculture Insurance.* http://www.fao.org/docrep/009/a0583e/ a0583e06.htm

M. Yu et al. 2013. Are Droughts Becoming more Frequent or Severe in China Based on the Standardized Precipitation Evapotranspiration. Index: 1951–2010? *Int. J. Climatol.* doi: 10.1002/joc.3701.

P.M. Zhai et al. 2005. Trends in Total Precipitation and Frequency of Daily Precipitation Extremes over China. *Journal of Climate.* 18. pp. 1,096–1,108.

Q. Zhan et al. 2006. Observed Trends of Annual Maximum Water Level and Streamflow During Past 130 Years in the Yangtze River Basin, China. *Journal of Hydrology.* 324. pp. 255–265.

Z.X. Zhang et al. 2009. Atmospheric Moisture Budget and Floods in the Yangtze River Basin, China. *Theoretical and Applied Climatology.* 95. pp. 331–340.

Q. Zhang. 2011. How to Fight Natural Disasters. *China Daily.* 28 June 2011. http://www.adb.org/ news/op-ed/how-fight-natural-disasters

W. Zhang et al. 2013. Numerical Simulation and Analysis of Saltwater Intrusion Lengths in the Pearl River Delta, China. *Journal of Coastal Research.* 29 (2). pp. 372–382. doi: http://dx.doi.org/10.2112/JCOASTRES-D-12-00068.1

Water-Related Disasters and Disaster Risk Management in the People's Republic of China

Disaster risk now presents one of the most serious threats to inclusive and sustainable socioeconomic development. In the People's Republic of China (PRC), the incidence of natural disasters—particularly water-related disasters—are on the rise, resulting in an increased exposure to and vulnerability of the population to disasters. Coupled with anticipated increases in the frequency and intensity of weather-related events due to climate change, the PRC's population is at heightened risk. This review focuses on water-related disasters, including identification of underlying causes, current management and policies to reduce risk, and opportunities for strengthening integrated disaster risk management in the PRC.

About the Asian Development Bank

ADB's vision is an Asia and Pacific region free of poverty. Its mission is to help its developing member countries reduce poverty and improve the quality of life of their people. Despite the region's many successes, it remains home to the majority of the world's poor. ADB is committed to reducing poverty through inclusive economic growth, environmentally sustainable growth, and regional integration.

Based in Manila, ADB is owned by 67 members, including 48 from the region. Its main instruments for helping its developing member countries are policy dialogue, loans, equity investments, guarantees, grants, and technical assistance.

ADB

ASIAN DEVELOPMENT BANK
6 ADB Avenue, Mandaluyong City
1550 Metro Manila, Philippines
www.adb.org