ADDRESSING CLIMATE CHANGE RISKS, DISASTERS, AND ADAPTATION IN THE PEOPLE'S REPUBLIC OF CHINA

ASIAN DEVELOPMENT BANK

ADB

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FOREWORD

Climate change poses a significant challenge to human security, socioeconomic development, and the environment. With global warming comes an increase in climate-related risks with more frequent and intense extreme weather events. With this increasingly uncertain future, it is vital for countries to be able to understand, manage, and plan for these climate risks. Many countries are already taking action, developing national strategies and action plans to mitigate and cope with climate change and its associated risks. However, there are still many challenges to be overcome when it comes to the development, coordination, and implementation of these strategies and plans.

The Asian Development Bank (ADB) recognizes the significant challenges faced by member countries to mitigate the causes of global warming and to adapt to the already unavoidable impacts of climate change. In response to this, ADB is increasing its support and emphasis on country-led climate change adaptation programs through building climate resilience and strengthening related policies, governance, and capacities.

Addressing Climate Change Risks, Disasters and Adaptation in the People's Republic of China aims to provide guidance for policy makers on how they can adapt to and address climate-related risks in the water, agriculture and natural resource sectors. The report provides an overview of climate change-related risks in the People's Republic of China (PRC) and presents approaches to reduce those climate risks and overcome barriers to incorporating adaptation measures. These measures should help inform policy, prioritize resource, finance allocations, and mainstream the integration of climate change adaption into everyday operational and development processes.

Integral to this study is the key message that successfully preparing for challenges and uncertainties brought on by climate change can be achieved with a good understanding of the risks and investment in actions to build resilience. Thus, ADB will continue to assist member countries to tackle the challenges of climate change to ensure sustainable environmental and economic development and to achieve poverty reduction where the needs of the people are met in the region.

Ayumi Konishi
Director General
East Asia Department

ABBREVIATIONS

ADB	Asian Development Bank
AR5	Fifth Assessment Report
DRM	disaster risk management
DRR	disaster risk reduction
GHG	greenhouse gas
IPCC	Intergovernmental Panel on Climate Change
NDRC	National Development and Reform Commission
PRC	People's Republic of China

I INTRODUCTION

Climate change is expected to have significant impacts on the socioeconomy and environment of the People's Republic of China (PRC), with ramifications for sustainable development and economic growth. The Asian Development Bank (ADB) recognizes the serious challenges to sustainable development posed by climate change, and is committed to assisting its member countries in identifying climate risks, reducing these risks through mitigation, adapting to risks as necessary, increasing resilience, and reducing vulnerability.[1] ADB has conducted a number of recent studies in the PRC and the Asia and Pacific region, and draws upon these findings in this study.[2]

This document (i) identifies specific risks from climate change to sustainable development; (ii) discusses the economic, social, and environmental implications of these risks to development in the water, agriculture, and natural resource sectors; and (iii) proposes adaptation and risk reduction policy recommendations, including rural–urban transformation as a potential risk reduction approach. The objectives of this document are twofold: inform decision makers regarding major climate change risks to development; and provide feasible policy recommendations for consideration to increase resilience and reduce vulnerability. The water, agriculture, and natural resource sectors are the primary focus of this paper.

[1] ADB. 2014. *Midterm Review of Strategy 2020: Meeting the Challenges of a Transforming Asia and Pacific.* Manila.
[2] ADB. 2013. *Economics of Climate Change in East Asia.* Manila.

II BACKGROUND

The PRC has experienced rapid economic growth that has provided significant increases in both household incomes and gross domestic product, which, based on preliminary accounting results for 2013, is approximately CNY56,884,500 million.[3] Average household income is approximately CNY7,917 for rural households and CNY24,565 for urban households.[4]

This growth, however, has resulted in severe environmental impacts, including widespread pollution, loss of biodiversity, increased disaster risks, and high emissions of greenhouse gas (GHG) that contribute to climate change. No figures are available for the costs of many of these impacts, but the average total annual cost of all disasters alone (excluding crop failures due to lack of data available) is approximately CNY517.08 billion.[5] Of the 120 million hectares of agricultural land, the average number of hectares affected by crop failure due to climate-related disasters such as severe storms, droughts, floods, subsidence, and landslides is approximately 39.17 million hectares.[6]

The PRC recognizes that these negative impacts will restrict future growth across all economic sectors, not just agriculture, and is taking action to reduce and mitigate these risks. For example, the PRC recently announced its intention to mitigate GHG emissions contributing to climate change through the addition of an absolute cap on GHG emissions as part of the next five-year plan, in addition to existing limits on GHG emissions intensity per unit of economic growth.[7] Although reducing emissions is required, this will unfortunately not be enough as some climate change impacts are now unavoidable. Adaptation measures are required to address these impacts.

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3 National Bureau of Statistics, People's Republic of China. http://www.stats.gov.cn/english/PressRelease/201401/t20140121_503020.html

4 Government of the People's Republic of China, National Bureau of Statistics. 2011. *Communiqué of the National Bureau of Statistics of People's Republic of China on Major Figures of the 2010 Population Census (No. 1)*. http://web.archive.org/web/20131108022004/http://www.stats.gov.cn/english/newsandcomingevents/t20110428_402722244.htm

5 Ministry of Civil Affairs of the People's Republic of China. http://www.mca.gov.cn/article/zwgk/mzyw/201310/20131000527449.shtml

6 Ministry of Agriculture of the People's Republic of China and the Ministry of Water Resources of the People's Republic of China. http://www.mwr.gov.cn/zwzc/hygb/zgshzhgb/

7 A. Vaughan and T. Branigan. 2014. [The People's Republic of] China to Limit Carbon Emissions for First Time, Climate Adviser Claims. *The Guardian*. 3 June. http://www.theguardian.com/environment/2014/jun/03/china-pledges-limit-carbon-emissions

The PRC submitted its First National Communication on Climate Change for the United Nations Framework Convention on Climate Change in 2004, which addressed climate change impacts and adaptation, in addition to emission levels and mitigation actions and policy. The PRC first incorporated specific adaptation tasks into the national agenda with its 2007 National Climate Change Program.[8] In its Second National Communication, completed in 2012, the PRC committed to developing a national adaptation policy framework. In 2013, the PRC developed a National Adaptation Strategy that lays out clear expectations as to the types of adaptation measures to be implemented.[9] These include enhancing risk management, improving relevant standards, and improving disaster response systems. The agenda is ambitious, ranging from human health to infrastructure. Although it is essential to address new adaptation issues in the PRC's Thirteenth Five-Year Plan, 2016–2020 there are financial and human resource constraints to implementation. Prioritization based on time frames for expected climate change impacts, climate risk assessments, and the most urgent challenges are required.

[8] Government of the People's Republic of China, National Development and Reform Commission (NDRC). 2007. *National Climate Change Program.* Beijing.

[9] Government of the People's Republic of China, NDRC. 2013. The People's Republic of China's National Strategy for Climate Change Adaptation (Draft). Beijing.

III PROJECTED CHANGES IN CLIMATE

The United Kingdom's Met Office climate change projections for the PRC by 2100 indicate that temperatures are expected to increase by up to 4.5°C in the north and west, and by up to around 3°C in the southeast, compared to 1960–1990 averages. Increases in precipitation of up to 20% in the northeast are projected, with the southeast receiving minimal or no increase. Agreement among climate models is extremely high for temperature; however, model projections are highly variable for precipitation throughout the PRC.[10]

As part of its assessment of climate risks, ADB recently conducted a study of 13 of the PRC's provinces including the capital Beijing, where development projects are being implemented or processed.[11] The projected changes in temperature and precipitation for the A1B emissions scenario are summarized in Map 1.[12] In the areas studied, the annual mean temperature was projected to increase by 1.5°C–2.4°C from 2031 to 2040, and by 2.3°C–3.0°C from 2051 to 2060. These findings are not significantly different from those of the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5).

Fujian, Guangdong, Hubei, Hunan, Jiangxi, and Yunnan provinces are projected to have decreases in precipitation, but increases are projected in the remaining seven study provinces (Anhui, Gansu, Henan, Jiangsu, Qinghai, Shaanxi, Shandong). However, projected changes are relatively small within the range of historical variability; and there does not appear to be a seasonal shift in future precipitation. It should also be noted that baseline precipitation for Gansu and Qinghai provinces is quite low compared to the other provinces, and that the large precipitation increases are relative to Gansu and Qinghai provinces' baseline precipitation levels.

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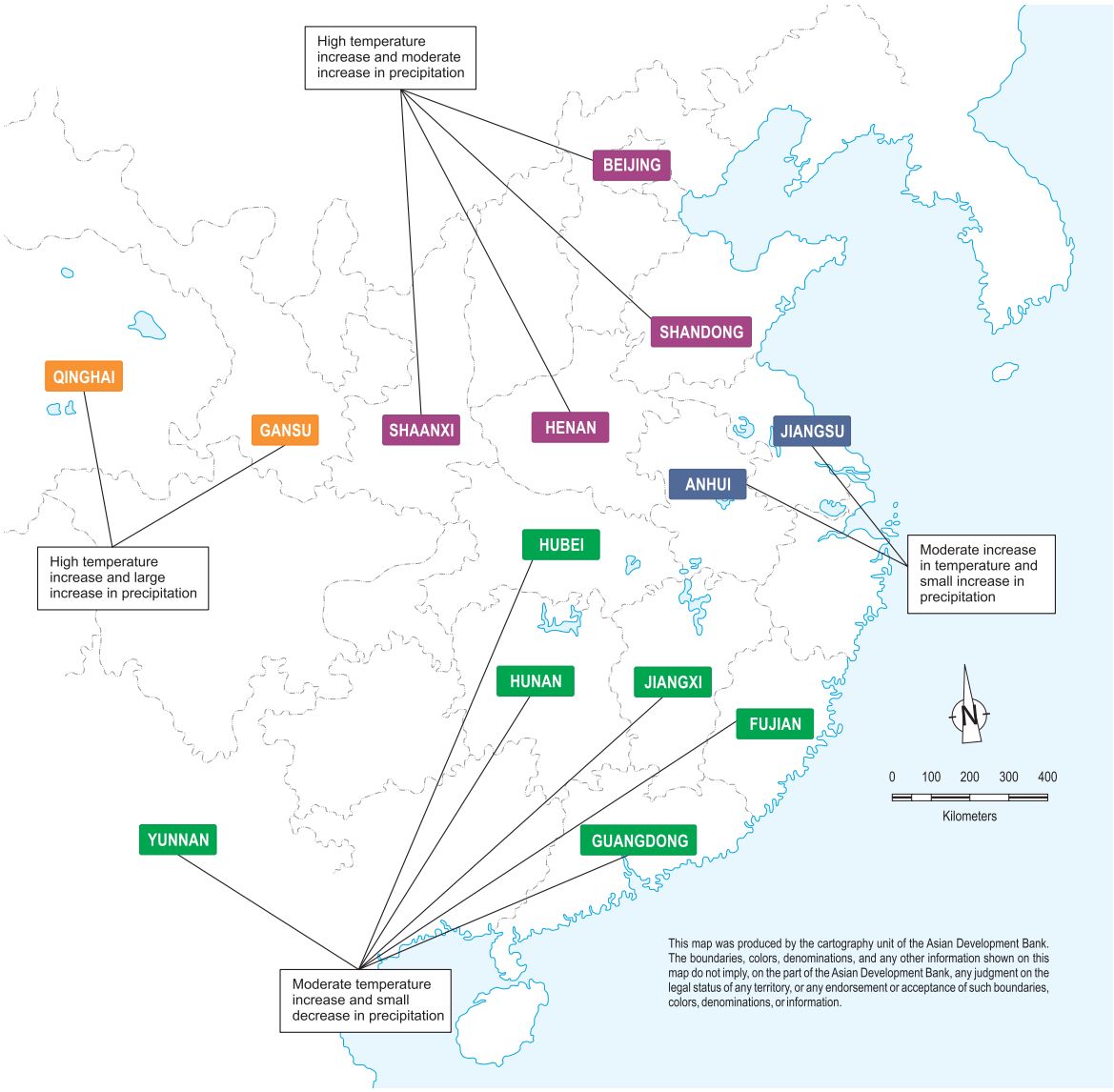
10 Met Office. 2012. *Climate: Observations, Projections, and Impacts, [The People's Republic of] China.* http://www.metoffice.gov.uk/media/pdf/4/p/China.pdf

11 ADB. 2014. *EAER Staff Guidance: Assessing Climate Change Risks in the PRC and Mongolia* (Internal ADB tool and document). Manila. Province selection was based on the portfolio of the Environment, Natural Resources, and Agriculture Division of ADB's East Asia Department.

12 A1B is an emission scenario for climate modeling. The International Panel on Climate Change Special Report on Emission Scenarios A1B assumes a peak in the global population around 2050 with subsequent population decline, economic growth that is very rapid, technological advances that are energy-efficient, and a more balanced approach to energy sources. International Panel on Climate Change. 2000. *IPCC Special Report Emissions Scenarios: Summary for Policy Makers.* https://www.ipcc.ch/pdf/special-reports/spm/sres-en.pdf

Map 1: Climate Change Summary for Beijing and 13 Provinces in the People's Republic of China



Note: Temperature changes are defined as low (≤ to 1.5°C in 2030 and 2°C in 2050), medium (> 1.5°C in 2030 and 2°C in 2050), and high (> 2°C in 2030 and 3°C in 2050) relative to the 1960–1990 baseline. Precipitation changes are defined as small (< 5%), moderate (5%–10%), and large (> 10%) relative to the 1960–1990 baseline for that location.

Source: ADB. 2014. *EAER Staff Guidance: Assessing Climate Change Risks in the PRC and Mongolia* (Internal ADB tool and document).

Changes in potential evapotranspiration, runoff, and soil moisture are generally projected to be minimal for 11 of the 14 provinces examined. However, the projections in Gansu, Jiangxi, and Qinghai are for increases in potential evapotranspiration and decreases in runoff and soil moisture. In general, severe storm events are expected to be more variable and greater in intensity across the PRC.

IV VULNERABILITY AND RISKS FROM CLIMATE CHANGE

A. Vulnerability

The PRC is vulnerable to climate change impacts, 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 (Maps 2 and 3). Major climate and climate change hazards include flooding due to extreme storms, sea-level rise, storm surges, glacial and/or permafrost melt, droughts, and heat waves. Secondary impacts include subsidence, coastal land loss, forest and grassland fires, saltwater intrusion, desertification, land degradation, and landslides.

Approximately 154 million people (11.4%) of the PRC population of 1.35 billion, plus affiliated infrastructure, are located in low-elevation coastal zones.[13] Major climate-related coastal hazards include flooding and potential increases in the frequency and/or intensity of severe storms and storm surges. The PRC is expected to have one of the highest global exposures to sea-level rise, with 14 coastal port cities vital for economic commerce and trade affected.[14]

The PRC's infrastructure in the central, eastern, and southern provinces is most vulnerable (Map 3). Cyclones and flooding are the primary hazards. Roads, important for the transport of agricultural goods (as well as other services), however, are vulnerable throughout the PRC due to the higher temperature increases expected in the north and west, which can lead to construction and maintenance problems depending on the materials used, as well as subsidence (climate and nonclimate-related).

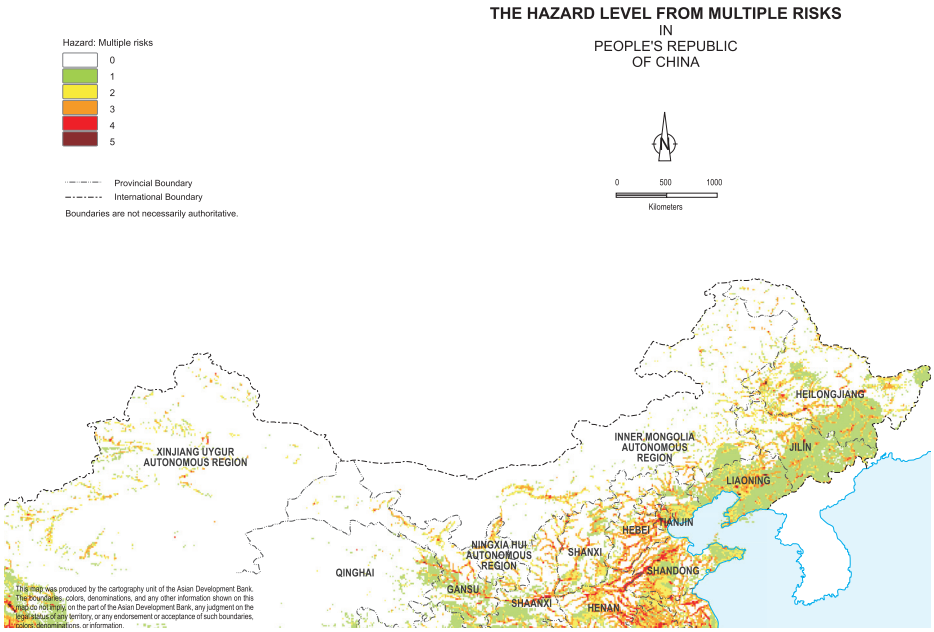
Levels of undernourishment in the PRC are estimated to be between 5% and 9% of the population.[15] Global-scale studies of food security vary in their conclusions for the PRC. However, studies generally project that the country will become less food-secure with climate change.

[13] Center for International Earth Science Network. 2012. *Low Elevation Coastal Zone Urban–Rural Estimates, Global Rural–Urban Mapping Project (GRUMP), Alpha Version.* http://sedac.ciesin.columbia.edu/data/collection/lecz; http://www.adb.org/sites/default/files/ki/2013/pdf/PRC.pdf

[14] S. Hanson et al. 2011. A Global Ranking of Port Cities with High Exposure to Climate Extremes. *Climatic Change.* 104(1): 89–111.

[15] N. Arnell et al. 2010. The Implications of Climate Policy for Avoided Impacts on Water and Food Security. *Work Stream 2, Report 6 of the AVOID Programme.* AV/WS2/D1/R06. London: Department for Energy and Climate Change.

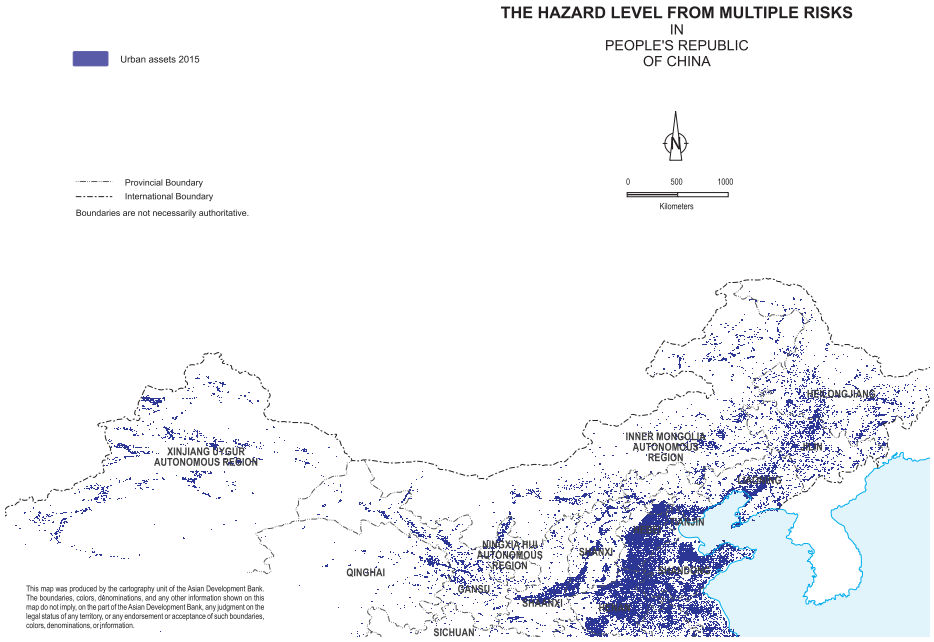
Map 2: Risks from Tropical Cyclone, Flood, and Landslides Induced by Precipitation



Note: The unit is an estimated risk index ranging from 1 (low) to 5 (extreme).

Sources: ADB. 2014. *Water-Related Disasters and Disaster Risk Management in the PRC.* Internal ADB report prepared for the PRC Country Water Assessment. Manila; UNEP/GRID-Geneva. http://preview.grid.unep.ch/index.php

Map 3: Location of Urban Assets in the People's Republic of China



Sources: ADB. 2014. *Water-Related Disasters and Disaster Risk Management in the PRC.* Internal ADB report prepared for the PRC Country Water Assessment. Manila; UNEP/GRID-Geneva. http://preview.grid.unep.ch/index.php

The PRC could be a food-importing country as of 2050.[16] Most studies predict declines in the PRC's major crops (rice, wheat, and maize) in the next 2–3 decades. Wheat is the most affected.

B. Brief Overview of Climate Change-Related Risks

Global-scale studies agree that parts of the PRC currently suffer from a moderate to high level of water stress. This includes Beijing, Hebei Province, Inner Mongolia Autonomous Region, Shanxi Province, and northern PRC. One recent study projects a gap of 201 billion cubic meters (m^3) between estimated water demand in 2030 and currently available supplies nationally, equivalent to roughly 32% of current supplies.[17] However, 20% of the PRC's population may have decreased water stress due to projected increases in levels of precipitation.[18]

Flood risk projections (risk of occurrence) are highly variable—ranging from a 20% decline to an 80% increase—with an average increase of approximately 10% by 2030, which increases to 20% by 2100 (footnote 10). Climate-related coastal flooding is impacted by precipitation, sea-level rise, severe storms, storm surges, and subsidence. Climate-related inland flooding is influenced by precipitation, severe storms, glacial and/or snow melt, subsidence, and droughts (hardened soils lose absorptive capacity).

There is no clear trend regarding cyclone frequency projections. However, cyclone intensity in the western Pacific basin is projected by a number of studies to increase considerably.[19]

Storm surges are impacted by cyclone or storm intensity, sea level, and natural or artificial barriers. Storm surges are expected to intensify by approximately 10% with a sea-level rise of 1 meter (m).[20]

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16 M. Falkenmark, J. Rockström, and L. Karlberg. 2009. Present and Future Water Requirements for Feeding Humanity. *Food Security*. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.469.9428&rep=rep1&type=pdf

17 2030 Water Resources Group. 2009. *Charting Our Water Future: Economic Frameworks to Inform Decision-Making.* New York: McKinsey & Co.

18 AVOID 2. http://www.avoid.uk.net/

19 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(2): 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: 2378–2396.

20 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.

Sea-level rise is projected at 0.29 m to 0.51 m by 2100 under a business-as-usual global scenario, with an affiliated loss of approximately 27 square kilometers (km^2) annually (footnotes 2 and 10). Under these estimates, the PRC is expected to lose about 19%–22% of its coastal wetlands by 2050 (footnote 2). However, the newest IPCC Fifth Assessment Report estimates of sea-level rise for 2081–2100 (relative to 1986–2005) are higher.[21] Mean sea-level rise estimates based on Coupled Model Intercomparison Project Phase 5 climate model projections and process-based models of glacier and ice sheet surface mass balance range from 0.45 m to 0.82 m for the representative concentration pathway scenario RCP8.5, which is characterized by rising greenhouse gases throughout the 21st century, and the scenario corresponding most closely to the current global trajectory. Sea-level rise could result in the displacement of approximately 0.5 million to 1 million people at a cumulative cost of around $150 billion by 2050; with an additional $50 billion per year in coastal economic damages (footnote 2).

Areas affected by droughts in the PRC are reported to have increased by ~3.7% per decade since the late 1990s, with extreme drought becoming more frequent in general, and persistent multiyear severe droughts increasing in the northern, northeastern, and northwestern PRC.[22] Severe droughts impact human health, biodiversity, agriculture, and the economy. For example, the major drought in the PRC in 2006 affected drinking water availability for 18 million people, reduced crop yield by 12%, and resulted in significant economic losses.[23] Potential damages of droughts have been reduced, but not eliminated, through improvements in transportation of goods (including bottled water), communications, and response time.

Salt water intrusion is increasing, due to the combination of climate change impacts, overextraction of ground water, dredging, and other factors. Aquifers in the coastal zones of Heibei, Liaoning, and Shandong have been impacted by saltwater intrusion. Thousands of hectares of farmland have been damaged and pumping wells have been abandoned.[24] The southern branch of the Yangtze connects to Chenhang Reservoir, the second largest

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21 T. F. Stocker et al. 2013. Technical Summary. *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge and New York: Cambridge University Press.

22 M. Yu et al. 2013. Are Droughts Becoming More Frequent or Severe in [the People's Republic of] China Based on the Standardized Precipitation Evapotranspiration Index: 1951–2010? *International Journal of Climatology*. 34(3). pp. 545–558.

23 Met Office. 2012. *Climate: Observations, Projections and Impacts.* http://www.metoffice.gov.uk/media/pdf/7/9/COP18_Factsheet_-_China.pdf

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

source of freshwater for Shanghai. Since 1999, water supplies have been threatened by saltwater intrusion during the dry season. This problem has been exacerbated by increased demand from economic activities.[25]

Sichuan, Yunnan, and the eastern part of Tibet Autonomous Region are hotspots for precipitation-related landslides.[26] Landslide frequency throughout the PRC is highly variable, ranging from none to almost 160, with an average of 40-plus per year, although this does not differentiate climate-related from tectonic-related landslides.[27]

Subsidence is a problem throughout the PRC, with much of the current subsidence due to overextraction of ground water, and thus only indirectly related to climate at present. However, permafrost melt, clay soil shrinkage, and karst collapse can be directly impacted by climate change; and aquifer recharge is impacted by temperature, evapotranspiration, and precipitation.

The PRC's 3.63 million km^2 of karst is subject to collapse from carbonic acids in precipitation and ground water. As of 2000, there were more than 1,400 karst collapses throughout the PRC.[28] Karst collapses are concentrated in the Guangxi Zhuang Autonomous Region, Guizhou, Hebei, Heilongjiang, Hubei, Hunan, Jiangxi, Liaoning, Shandong, Sichuan, and Yunnan.

Both agriculture and fisheries productivity are expected to decline. Changes in precipitation and temperature are expected to decrease agricultural productivity by approximately 10% by 2050, with wheat yield declining nearly 24% under the driest scenario (footnote 2). Droughts, severe storms, and subsidence will impact freshwater fisheries; while marine fisheries will be impacted by higher temperatures leading to the potential loss of coral reef nurseries and ocean acidification.

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[25] P. Xue et al. 2009. Saltwater Intrusion into the Changjiang River: A Model-Guided Mechanism Study. *Journal of Geophysical Research*. 114(C2). http://onlinelibrary.wiley.com/doi/10.1029/2008JC004831/pdf

[26] F. Nadim et al. 2006. Global Landslide and Avalanche Hotspots. *Landslides.* 3(2): 159–173; see also footnote 14.

[27] C. Liu et al. 2013. Susceptibility Evaluation and Mapping of [the People's Republic of] China's Landslides Based on Multi-Source Data. *Natural Hazards.* 69(3): 1477–1495.

[28] M. Lei, X. Jiang, and L. Yu. 2002. New Advances in Karst Collapse Research in [the People's Republic of] China. *Environmental Geology.* 42(5): 462–468.

C. Current Policies and Strategies, and Gaps and Deficits

1. Current Policies and Strategies

The National Development and Reform Commission (NDRC) currently leads the development of the climate change adaptation strategy. The PRC has made significant progress in policies and regulations regarding climate change adaptation since Agenda 21 in 1992. The National Climate Change Program was developed and implemented in 2007, and both the Eleventh and Twelfth Five-Year Plans for National Economic and Social Development of the PRC specifically included adaptation measures, such as hydrological projects for disaster management and mitigation, introducing new technologies for dryland agriculture, implementing the climate smart agriculture project in major grain production bases, promoting energy saving and greenhouse gas reduction, and strengthening management of water resources. New policies and regulations have been enacted across the water, agriculture, forestry, health, and infrastructure sectors. These include (i) the joint issuance from the Ministry of Finance and the Ministry of Agriculture Notice on Promoting the Dryland Agriculture Technology; (ii) Ministry of Water Resources Opinions of the State Council on Implementing the Strictest Water Resources Management System; (iii) tightened administration of water drawing permission and water resource fees, and measures to implement the National Drought Control Plan; as well as (iv) the State Forestry Administration Plan for Climate Change Adaptation in Forestry. The National Health and Family Planning Commission has issued the Scheme for the Prevention and Control of MERS Epidemic, the Prevention and Control of Human-infected H7N9 Epidemics, the Handbook on the Prevention and Control of Cholera, as well as the Urgent Notice on Offering Emergency Public Health Services in the Wake of Natural Disasters. A draft National Adaptation Strategy has been developed by the NDRC.[29]

In water infrastructure and irrigation, 38.1 billion m^3 of reservoir capacity was added; 17,080 kilometers of embankments were constructed and/or reinforced; and 6,240 reservoirs were strengthened. Farmland investments have resulted in an additional 50 million *mu* of irrigation area, with an additional 400 million *mu* incorporating water conservation technologies.[30] Urban and rural drinking water sanitation has been improved.[31]

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[29] Government of the People's Republic of China, NDRC. 2014. *[The People's Republic of] China's Policies and Actions on Climate Change.* Beijing.

[30] *Mu* is a traditional Chinese unit of land measurement (1 *mu* = 1/15 hectare).

[31] ADB. 2012. *Green Cities.* Manila.

Land use practices have been improved to increase the adaptive capacity of ecosystems. Conservation tillage technology has been adopted for 5.6 million hectares of farmland, and 25.29 million hectares of afforestation areas were created with total forest cover reaching 195 million hectares (20.4%). Grassland vegetation has been improved, with the coverage rate reaching 53%. Approximately 1.5 million hectares of protected wetlands were created; another 80,000 hectares of wetlands were restored; and over 20,000 small watersheds were improved. Land use and zonation practices have been reviewed in vulnerable areas (footnote 31).

Monitoring and early warning systems have been developed for some climate-related natural disasters, such as extreme weather events. The impacts of coastal sea-level changes, such as coastal erosion, have been surveyed. A disaster response, prevention, and control framework has been developed, along with contingency health plans.

2. Gaps and Needs

Despite substantial progress, there remain gaps and weaknesses in the PRC's fundamental capacity to address climate change. An incomplete legal framework undermines efforts to fully incorporate climate change factors into planning. Funding mechanisms for adaptation efforts are not established, and inadequate funds are allocated in current government budgets to implement adaptation measures. There is also inadequate access to new technologies and technological support. These issues undermine effective adaptation efforts, leaving a large gap between the level of need and actual capacity for implementation (footnote 31).

Current technical standards for infrastructure construction, operation, and maintenance do not incorporate climate change projections or their potential risks (footnote 31). Current critical rural–urban infrastructures, such as telecommunications, electricity, water supply, and heating, which support the water, agriculture, and natural resource sectors, are not designed to withstand extreme weather events. This applies as well to the mining, construction, transport, tourism, and other climate-sensitive sectors.

Feasibility studies for major development projects take into account relevant national laws, regulations, technical standards and requirements for each sector based on the type of the project. Feasibility studies are required to include analyses of market, technical, financial, organizational, legal, economic, and social risks; but no assessment is required for climate change risks (footnote 31). Requirements and guidance for the conduct of

environmental impact assessments also do not include an assessment of climate change risks. Lack of incorporation of these risks poses significant economic, environmental, and social costs in the future.

Monitoring and early warning systems for agriculture, water, forest fires, pests, and human health need to be developed. Ecosystems continue to be degraded, with resulting desertification, soil erosion, loss of biodiversity and wetlands, and reduced forest and grassland quality.

Although advances have been made in agriculture and water management, the scale and scope of measures adopted are insufficient. Climate forecasts are not regularly incorporated into long-term planning and decision making regarding crop selection and adoption of water conservation measures. Flood control mechanisms and drainage systems are also inadequate.

V

POTENTIAL APPROACHES TO REDUCING CLIMATE RISKS AND OVERCOMING BARRIERS TO INCORPORATING ADAPTATION MEASURES

A. Lessons Learned: International Experience in Incorporating Adaptation Measures

1. Mainstreaming Adaptation in National and Sector Planning

Successful adaptation efforts at the project, community, or ecosystem level are most likely to succeed if they reflect a strong commitment to adaptation and resilience-building as essential components of development planning; and if they are embodied in national and sector laws, policies, strategies, and budgets. For example, India's approach to climate change is based on the assertion that "measures that promote our development objectives.. also yield cobenefits for addressing climate change effectively." The strategy emphasizes technological innovation, reflecting the assumption that by prioritizing India's need for climate-friendly and resilient technologies (both mitigation and adaptation), the nation positions itself as a leader in these technologies, supporting internationally competitive industries. These priorities are made explicit in India's National Action Plan on Climate Change and implemented through eight national missions, including water, sustainable agriculture, and strategic knowledge for climate change.[32]

Indonesia's National Action Plan for Climate Change Adaptation provides another example, emphasizing building resilience in economic development (food security, energy security); livelihoods (health, human settlement, and infrastructure); environment (ecosystems and biodiversity); special areas (urban, coastal, and small islands); and supporting systems (stakeholder capacity, climate information, monitoring and evaluation).[33] Viet Nam's National Climate Change Strategy takes a different approach, establishing a research agenda.[34] The strategy emphasizes knowledge generation in areas, including proactive disaster preparedness,

[32] Government of India, Prime Minister's Council on Climate Change. 2008. *National Action Plan on Climate Change.* New Delhi.
[33] Republic of Indonesia, Ministry of National Development Planning (BAPPENAS). 2012. *National Action Plan for Climate Change Adaptation (RAN-API) Synthesis Report.* Jakarta.
[34] Socialist Republic of Viet Nam, Prime Minister. 2011. *National Climate Change Strategy.* Ha Noi.

climate information systems, food and water security, vulnerable coastal areas, sustainable forestry, and biodiversity conservation.

2. Supporting Adaptation at Regional Level through Spatial Planning and Risk Mapping

Climate-related hazards, as well as exposure and vulnerability to these hazards, are often geographically explicit. Examples include the risks to low-elevation coastal zones (including islands) from the combined impacts of sea-level rise, intensified tropical storms, and storm surges (in some instances exacerbated by riverine flooding); the risks to locations on steep slopes from the combined hazards of high runoff from heavy precipitation, slope instability (landslide) and possibly from geotechnical hazards; and the risks to midcontinent regions from prolonged and intensified droughts. An understanding of the spatial character and distribution of climate-related risks can improve the targeting and effectiveness of adaptation planning and investment.

Several international studies have been conducted that provide spatially indexed estimates of climatic disaster risk, including the United Nations International Strategy for Disaster Reduction[35] for drought, cyclones, and flooding; and the Socioeconomic Data and Applications Center for spatial distribution of population and assets with reference to sea level and related indicators.[36] Several private corporations and consulting groups have also utilized geospatial mapping and simulation techniques to develop estimates of the spatial distribution of risk from climate change and related hazards, among which Maplecroft is widely cited.[37]

Many successful regional applications of hazard mapping can also be identified. Albay Province in eastern Luzon, Philippines is one of the most disaster-prone locations on the planet. The province is exposed to a wide range of climatic hazards, including direct exposure to several typhoons each year, inland and coastal flooding, sea-level rise, as well as geohazards, including volcanic eruption, earthquake, and tsunami.[38] The combination of frequent eruptions of the Mayon volcano and increasingly intense precipitation events creates a high risk of deadly landslides. As an important

[35] United Nations International Strategy for Disaster Reduction. 2009. *Global Assessment Report on Disaster Risk Reduction.* http://www.unisdr.org/we/inform/publications/9413

[36] Center for International Earth Science Network. 2012. *Socioeconomic Data and Applications Center (SEDAC).* http://sedac.ciesin.columbia.edu

[37] Verisk Maplecroft. http://maplecroft.com/about/news/ccvi_2013.html

[38] The Philippines experiences roughly 20 typhoons per year on average, and Albay Province is exposed to three to five major storms in a typical recent year. Source: J Salceda. 2012. Leadership. Presentation at the Sustainable Asia Leadership Overview Program. Manila. 10–14 September.

component of its "zero casualty" program designed to shift emphasis from disaster recovery to prevention and to integrate disaster risk management (DRM) with climate change adaptation, Albay Province has developed a comprehensive set of risk maps, supporting transformational changes in zoning, land use planning, and disaster evacuation planning, as well as location of vulnerable communities. The result is a dramatic decrease in annual casualties from combined natural hazards, with many recent years of not experiencing disaster-related deaths. The IPCC in its AR5 has identified Albay Province as an example of leading practices in the area of climate change adaptation and DRM.[39]

Spatial risk mapping is a well-known approach to designing, targeting, and evaluating climate change adaptation activities. In one recent example, ADB and its partners at the World Bank and the Japan International Cooperation Agency used geographical information systems, digital elevation models, climate change projections, and hydrologic modeling to evaluate the likely physical and economic impacts of climate change on three major metropolitan areas in Southeast Asia—Bangkok, Ho Chi Minh City, and Manila—identified by Maplecroft as among global cities at extreme risk from climate change.[40] Design scenarios based on model projections of sea-level rise and extreme tropical storms were used to assess the vulnerability of key infrastructure, including transportation and energy networks, irrigated areas, and communities; and to evaluate the effectiveness of proposed structural flood control measures. The use of spatial modeling with climate change scenarios enables economic analysis of adaptation options, including an understanding of the costs of doing nothing.

3. Integrating Climate Change Adaptation and Disaster Risk Management

There is a strong consensus among experts and international development professionals on the need to coordinate and integrate climate change adaptation and disaster risk reduction (DRR) and DRM. The complementarity between adaptation and DRR and DRM was identified in the IPCC Special Report on Managing the Risks of Extreme Events and Disasters, and given further emphasis in the AR5 (footnote 40).[41] Since anticipated disaster risks associated with climate change entail more frequent, prolonged, and/or intensified manifestations

[39] IPCC. 2014. Chapter 15: Adaptation Planning and Implementation. *AR5 WGII.* Geneva.
[40] World Bank. 2010. *Climate Risks and Adaptation in Asian Coastal Megacities—A Synthesis Report.* http://siteresources.worldbank.org/EASTASIAPACIFICEXT/Resources/226300-1287600424406/coastal_megacities_fullreport.pdf
[41] IPCC. 2012. *IPCC Special Report on Managing the Risks of Extreme Events and Disasters.* Geneva.

of current climate-related risks (flood, drought, tropical storms), it follows that approaches that are effective in reducing risks under the present climate provide a logical foundation for adaptation interventions in an altered climate. The successful integration of adaptation and DRR and DRM objectives and approaches can be observed in the "zero casualty" program of Albay Province described above. Key elements common to adaptation and DRR and DRM include improved skills in climate monitoring and forecasting (from daily to decadal scales) and incorporation of this information in early warning systems; as well as strengthened adaptive capacity and resilience at community level.

The successful integration of climate change adaptation and DRR and DRM are often made difficult by conflicting institutional mandates and sources of funding among other factors. ADB's Environment Operational Directions, 2013–2020: Promoting Transitions to Green Growth in Asia and the Pacific; and the Operational Plan for Integrated Disaster Risk Management, 2014–2020 both clearly articulate a common goal of integrating climate change adaptation and DRR and DRM.[42]

4. Urban Resilience and Green Infrastructure

"Green" infrastructure and green approaches to urban development are being used effectively to increase the resilience of urban areas to climate change and natural disasters, as well as more livable, aesthetic, and sustainable urban environments.[43] Green approaches to urban development include both engineering (porous pavement, hydrologic disconnection, and infiltration basins) and ecosystems-based approaches (reestablished urban floodplains, urban forestry, green roofs, and linked green spaces). Green approaches can attenuate stormwater runoff, thus reducing urban flood risks, improving runoff water quality, and reducing ambient urban temperatures through evaporative cooling. Some of these approaches also provide mitigation cobenefits, for example increased energy efficiency (climate change mitigation) and green roofs reducing demand for energy-intensive air-conditioning.[44]

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42 ADB. 2013. *Environment Operational Directions, 2013–2020: Promoting Transitions to Green Growth in Asia and the Pacific.* Manila; and ADB. 2014. *Operational Plan for Integrated Disaster Risk Management, 2014–2020.* Manila.

43 ADB. 2012. *Green Cities.* Manila.

44 IPCC. 2014. WGII, Chapter 8: Urban Areas. *Fifth Assessment Report*. Geneva.

B. General Approach to Reducing Climate Risk Taken by the Asian Development Bank

Reducing climate risks to sustainable development requires (i) awareness of the historical climate and climate change projections for the area being developed, (ii) understanding of the potential impacts and implications of projected changes, and (iii) specific actions to reduce the risks (adaptation measures and integrated DRM) in the development area that is vulnerable. ADB now requires preliminary climate risk screening of all development projects that it finances.

Risk screening procedures should both identify and characterize specific climate change impacts and their likely consequences within the project context.[45] Detailed climate risk and vulnerability assessments are recommended if preliminary screening indicates medium or high levels of risk. These assessments should be conducted during project preparation so that specific risk reduction measures can be incorporated into the project design. Preliminary climate risk assessments (screening) can be made using checklists; commercial software tools (such as the AWARE for project jointly developed by Acclimatise-UK and ADB); or more individualized tools such as developed specifically for the Environment, Natural Resources, and Agriculture Division of ADB's East Asia Department (footnote 11).[46]

Due to the complexity and uncertainties that define climate risks and vulnerability, particularly at the project level and in a specific socioeconomic context, climate risk management can be a challenging activity. There are gaps in the information resources currently available to integrate climate risk management and climate-proof development projects. ADB has developed technical guidance reports to assist operational staff, developing member countries, and clients to manage climate-related risks throughout the project cycle. This package reflects the growing experience in ADB and its partners in pilot testing a wide range of climate-proofing approaches, and includes technical notes for climate-proofing vulnerable investment in critical sectors.[47]

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45 ADB. 2014. Climate Risk Screening and Assessment of Projects. *ADB Memorandum.* 3 March. Manila.
46 ADB engaged Acclimatise-UK to modify their rapid risk assessment tool "AWARE for Projects."
47 ADB. 2013. *Building Resilience to Climate Change: Adaptation Technical Resources.* http://adb.org/sites/default/files/pub/2013/building-resilience-to-climate-change.pdf

C. Overcoming Barriers to Incorporating Adaptation Measures

There are a number of specific actions that can increase resilience, reduce vulnerability, and improve adaptation to climate change impacts in development projects. In the agriculture, natural resource, and water sectors, adaption measures include increasing water storage infrastructure; improved agriculture and land management practices (for example, more efficient irrigation technologies and shorter duration crops); and water demand management. ADB has prepared sector-specific technical guidance for these and other development sectors.[48] In addition, ADB has qualitatively evaluated specific adaptation technology options in six sectors: agriculture, coastal resources, DRM, health, transportation, and water.[49]

However, there can be significant barriers to implementation of potential adaptation measures. These include financial and time costs, cultural and knowledge constraints, current zonation and land use plans, and aspects of the regulatory framework, including perverse policy incentives.

1. Overcoming Cost Barriers

Adaptation costs for climate proofing across all sectors in the PRC have not been fully estimated, and detailed information regarding planned adaptation allocations in future budgets are not available. ADB is providing $1.11 billion for environmental activities and $1.20 billion for urbanization activities that may support adaptation, per ADB's country operations business plan, 2014–2016 for the PRC, but this is not clearly stated.[50] It is clear that at least for certain sectors, the costs of adaptation are lower than the estimated costs of damages attributable to climate change, and are thus economically justified. For example, the total annual adaptation costs for the coastal sector are estimated to range from $0.49 billion to $2.6 billion for low versus high sea-level rise (with cyclones). This is substantially lower than the estimated economic damages and residual damages of approximately $50.0 billion annually (footnote 2).

[48] See, for example, ADB. 2012. *Sector Briefing on Climate Change Impacts and Adaptation: Agriculture.* Manila.
[49] ADB. 2014. Technologies to Support Climate Change Adaptation in Developing Asia. Draft consultant's report. Manila.
[50] ADB. 2014. *Country Operations Business Plan: People's Republic of China, 2014–2016.* Manila.

Adaptation funds have been both provided and pledged by numerous ADB member countries to help support the newly established Green Climate Fund, the Kyoto Protocol Adaptation Fund, and others. However, funds mobilized or pledged to date are insufficient to meet anticipated global needs. Access to these funds by the PRC is likely to be limited, as the priority for allocation is to the least developed countries and small island nations.

It is therefore necessary that the PRC allocate resources in its official budgeting processes for required adaptation measures, where appropriate and feasible. Cost–benefit analyses and the calculation of marginal abatement cost curves could help the PRC prioritize adaptation measures. Revenues generated through newly developing domestic carbon markets, auctioning of allowances, and savings from improved resource efficiency and conservation could potentially be allocated to fund additional adaptation measures. At present, there are no detailed estimates of how much revenue could be generated, but the expectation is that the amount generated would be substantial. In addition, future tax revenues could also be allocated, as sustainable economic growth is predicated upon the adoption of adaptation measures that protect current revenue streams, and reduce losses from climate-related disasters, including floods, droughts, and severe storms.

2. Overcoming Cultural and Knowledge Constraints

Although the PRC is a world leader in research, there are few data available regarding ecological interrelationships and environmental impacts of the large-scale land and natural resource use decisions that have been made. The lack of ecological data makes it difficult to assess and predict climate change impacts on the natural resource base. Much of the research emphasis is on technology.

Few natural landscapes remain in the PRC, as culturally the emphasis is on managed and reshaped landscapes, and the control of ecological processes. In the past, development focus has been on maintaining economic growth, often at the expense of the environment. However, the PRC recognizes that increasing levels of environmental degradation are undermining resilience and the capacity to adapt to climate change. The PRC has recently taken strong legislative measures to address environmental degradation, but further measures are required. Local capacity to apply basic ecological principles to land and water use decisions still requires strengthening.

3. Overcoming Current Land Use and Land Use Plans

Current land use and land use planning are not based on the most ecologically appropriate use of the land, the potential environmental impacts, or future suitability based on climate forecasts. High levels of environmental degradation from poor land use, combined with a large coastal population, make the PRC highly vulnerable to climate impacts.

The PRC has begun to assess potential climate impacts, particularly in coastal urban areas; and is improving infrastructure to reduce flooding. Reforestation of steep slopes is being encouraged to increase water absorption and reduce flooding, as well as to reduce GHG emissions. However, lands currently used for agriculture are not necessarily well suited. Water is piped from the south into the north to meet irrigation needs of agricultural lands, as there is insufficient water available (from water bodies, aquifers or precipitation).

4. Overcoming Regulatory Barriers

Multiple laws and regulations related to disaster reduction (including climate change-related) have been passed. There is a comprehensive basis for the management of disaster prevention, reduction, and response. However, the legal framework is guided by the traditional principle of "one law for one event"; and each law or regulation targets one type of disaster event. This leads to overlapping regulations, and conflicts and contradictions between laws. As climate change is crosscutting, the regulatory problems are even more complex, involving agriculture, coastal management, energy, land use, and other sectors. There is a serious need for a review (based on policy implications) and consolidation of legislation on disaster reduction and climate change.

5. Rural–Urban Transformation as an Approach to Reduce Risks

The PRC is investing heavily in its rural–urban transformation, with over 50% urbanization as of 2010, and increasing at a rate of 5.5% per year.[51] Urbanization can decrease climate risks and help with adaptation, through restoration of ecological services on lands, increasing income diversification for the rural population, and improving access to services and information.

[51] ADB. 2013. *Strategic Options for Urbanization in the People's Republic of China: Key Findings.* Manila.

There has been a significant increase in urban development, but the rural population faces numerous barriers to migration.

Individuals require administrative support with securing the necessary paperwork required to access public services. Technical support is required to help individuals gain the necessary skill sets required for employment. Market incentives are required to incentivize private sector to create jobs and preferentially hire employees originating from rural areas.

VI CONCLUSIONS AND POLICY RECOMMENDATIONS ON ADAPTATION AND DISASTER RISK MANAGEMENT

The PRC is at significant risk to its food security and the capacity for sustainable economic growth if policy measures are not adopted and implemented in the near future. Recognizing this, the PRC has already taken several concrete actions to address risks from climate change and disasters. However, there remain areas that would benefit from increased investment of time and resources in the PRC's Thirteenth Five-Year Plan.

The following specific policy measures are recommended to complement the PRC's actions.

(i) Mainstreaming Integrated Disaster Risk Management and Climate Change Projections

Development and land use planning, budgeting, and infrastructure standards all need to incorporate DRM and climate change projections. Land use plans should be reevaluated given disaster hazard maps and climate change projections, and areas that are appropriate for future agriculture and infrastructure development should be identified. Policy incentives (e.g., insurance access, reduced interest loans, etc.) should be considered to ensure that new development is in appropriate areas, and new government-led infrastructure and development projects should be restricted to these areas.

(ii) Careful Assessment of Adaptation Measures

Adaptation measures require careful assessment given limited domestic and international resources. Different populations will require different measures. For example, rural populations will require technical and administrative support to diversify livelihoods and transition to urban centers (both potential adaptations). This support is necessary to help individuals gain the skills necessary for urban employment, the papers necessary to gain access to urban services, and market incentives to employers to create jobs and hire employees originating from the rural sector.

Additional research is required to better understand potential climate change impacts on the environment, and how improved environmental quality may increase local resilience. A detailed analysis of the costs, benefits, and suitability of various adaptation options for vulnerable

populations and economic sectors should be conducted. Initial efforts have been made in the adaptation technology sector. Criteria for prioritization should be selected, with adaptation measures subsequently rank ordered.

(iii) Investing Wisely in Adaptation Measures

Current official budgets do not allocate sufficient resources for adaptation. Based on adaptation priorities, additional resources should be incorporated into central, provincial, and local budgets. The PRC should conduct a detailed estimate of current needs versus available funds, and identify budgetary shortfalls and potential approaches for new revenue sources.

(iv) Encouraging the Use of Market Mechanisms

Insurance can reduce risks from disasters and climate change for specific individuals and governments, although in reality the risk is being reallocated to others. Mechanisms include catastrophe bonds, flood insurance, and crop insurance. It should be noted, however, that low-cost insurance may encourage greater risk exposure.

Revenues generated through carbon finance, including domestic carbon markets and the auctioning of allowances, may potentially be leveraged to provide an additional revenue source for finance of adaptation measures. The PRC's national carbon emissions trading scheme is still in development, with pilots being implemented. Detailed estimates should be made of the potential revenue stream as part of this process.

(v) Eliminating Perverse Policies and Subsidies that Undermine Adaptation Efforts and Increase Climate Risk

The PRC currently subsidizes the provision of water used by households and in agriculture and industry. This policy undermines conservation and water-use efficiency initiatives. Water subsidies lead to overextraction, degradation of water quality, and increased energy expenditures (in treating and distributing water resources). Elimination of subsidies would improve efficiency and resource conservation, and reduce nonrevenue water loss. The PRC should invest in quantifying the value of subsidies currently provided in the water sector, and the potential impacts of policy modifications to remove subsidies.

(vi) Promoting and Adopting Technological Innovations, Particularly those with Cobenefits

A number of new technologies have been developed that are appropriate and cost-effective. Many of these technologies have cobenefits, such as reducing GHG emissions, increasing resilience, or conserving biodiversity. Examples include "green concrete" that sequesters carbon (biostone—made from bacteria and sand, silica, fly ash, mushrooms or other organic materials), and can be used in new construction of climate-resilient infrastructure, or water-conserving energy efficient appliances.[52]

(vii) Standardizing Climate Change Risk Assessments and Incorporation into Required Feasibility Studies and Environmental Impact Assessments for Development Projects

Risk assessment helps ensure that scarce resources are used in a cost-effective manner, achieve the desired results, and are not wasted. Standardization ensures the quality of the risk assessment, including climate change risk assessments; and reduces the costs affiliated with constantly developing methodologies. Methods, approaches, and procedures for climate change risk assessment need to be selected, standardized, and applied consistently. This includes details regarding the type of information needed regarding climate change projections (is downscaling required or not); identifying potential environmental, economic, and social impacts that should be included in the assessment; the probability and strength (or degree of difference from the historical average) of the climate change parameter; the magnitude (size of area and portion or number of activities impacted) of the climate change parameter or event occurrence on development project activities; and the severity (impact on budget and/or success at achieving results) of the climate change parameter or event on the project activities. The risk is then defined based on these variables using an agreed upon methodology, for example, as the product of the probability and strength multiplied by the magnitude and severity.

Incorporation of climate change risk assessment during development project preparation has been adopted by several institutions to reduce financial risk. As part of due diligence, climate change risk assessment is now required by ADB during project approval. The PRC should strongly consider including review of climate change projections and consideration of climate proofing in its investment project approvals.

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[52] *Would you Live in a House Made of Sand and Bacteria? It's a Surprisingly Good Idea.* 2014. http://edition.cnn.com/2014/05/21/tech/innovation/would-you-live-in-a-house-made-of-urine-and-bacteria/index.html?hpt=hp_c3; *Biomason Built with Nature.* 2014. http://www.biomason.com/; *We Grow Materials.* 2014. http://www.ecovativedesign.com/

Addressing Climate Change Risks, Disasters, and Adaptation in the People's Republic of China

Climate change poses a significant challenge to human security, socioeconomic development, and the environment due to an increase in climate-related risks with more frequent and intense extreme weather events. It is vital for countries to identify climate risks, reduce these risks through mitigation, and adapt to these risks—thereby increasing resilience and reducing vulnerability. This study informs decision makers regarding major climate change risks to development and provides feasible policy recommendations for consideration to increase resilience and reduce vulnerability in the water, agriculture, and natural resource sectors of the People's Republic of China.

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.

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