世界资源研究所
WORLD RESOURCES INSTITUTE

EXECUTIVE SUMMARY

ACCELERATING CLIMATE-RESILIENT INFRASTRUCTURE INVESTMENT IN CHINA

Helen DING, Tian YU, Wenyi XI, Lu LU, Wee Kean FONG, Ying CAO, Shuya KUANG, Ying CUI, Jieyu ZHOU, Huixin LIU, Yinlong XU, Kuo LI

国家应对气候变化战略研究和国际合作中心
National Center for Climate Change Strategy and International Cooperation (NCSC)

中央财经大学绿色金融国际研究院
International Institute of Green Finance, CUFE

WRI.ORG.CN

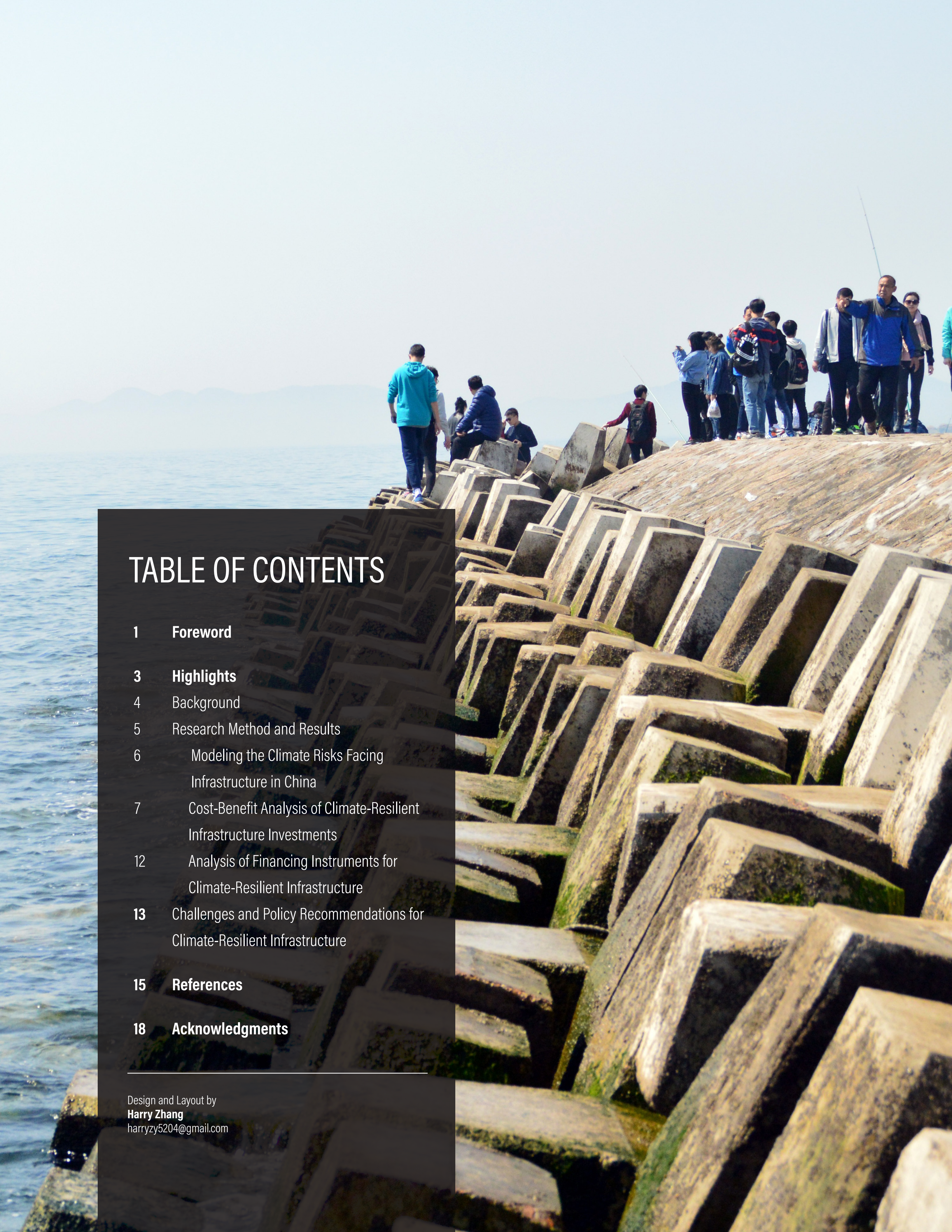


TABLE OF CONTENTS

Design and Layout by
Harry Zhang
harryzy5204@gmail.com

FOREWORD

The world has witnessed a relentless series of dramatic and devastating severe weather events over the past year. Floods and the "7.20" extreme rainstorm in China's Henan Province led to 302 deaths and the destruction of RMB 114.269 billion of economic value. Two consecutive days of heavy rain in Germany, Belgium, and the Netherlands led to catastrophic flooding and the deaths of more than 200 people. Meanwhile, North America suffered record-breaking heat waves and fires, and storm surge threatened coastal cities around the world. As global temperatures rise, deadly and expensive events are happening with increasing frequency.

According to the latest report of the Intergovernmental Panel on Climate Change (IPCC), the average global temperature is on course to rise 1.5°C above pre-industrial levels within a few decades. This is earlier than expected, and means we are set to face more dramatic climate fluctuations and more extreme weather events. To protect their people and assets against catastrophic and irreversible damage, it is urgent for all countries to accelerate investment in climate adaptation measures. A major recent report from the Global Commission on Adaptation estimated that investment in climate-resilient infrastructure can generate a global benefit-cost ratio of close to 5:1.

China is among those most affected by extreme weather events, and it also has great potential to play a leadership role in exploring solutions. There is a unique window of opportunity for China to accelerate the construction of climate-resilient infrastructure as it begins to implement its 14th Five-Year Plan, which sets building "New Infrastructure" as one of the policy priorities. Integrating climate adaptation measures into the design and construction of this New Infrastructure will not only make China more resilient in the face of future climate impacts but also create jobs and provide economic advantages during the post-COVID-19 economic recovery.

WRI's new report showcases the tangible investment returns for China's climate-resilient infrastructure and investigates potential financing opportunities to fill the annual funding gap of nearly RMB 500 billion over the next five years. It finds that every RMB 1 invested in climate resilience can bring RMB 2–20 of return over a period of 30 years, in terms of avoided damages, economic benefits, and social and environmental benefits (the "Triple Dividends"). The report examines three case studies: water-saving irrigation facilities in Ningxia, sponge city construction in Wuhan, and green-grey sea dikes construction in Shenzhen.

WRI hopes that this report's findings can inform China's National Climate Change Adaptation Strategy 2035, accelerate climate adaptation action across government at all levels during the 14th Five-Year Plan, and equip policymakers and researchers with a concrete research base and methodological framework to advance climate adaptation rapidly and at scale.

Ani Dasgupta
President and CEO
World Resources Institute

HIGHLIGHTS

- In August 2021, the latest report of the Intergovernmental Panel on Climate Change (IPCC) suggests that the 1.5°C global warming threshold is likely to be breached in the next 20 years. If such warming continues, it will result in irreversible impacts on nature and ecosystems. While continuous efforts are essential to mitigate climate change, we must simultaneously accelerate the investment in climate adaptation to build resilience to climate change and reduce any associated damage.

- This report systematically defines and analyzes climate risks and the corresponding climate-resilient infrastructure (CRI) in China. Building on three case studies, it evaluates future agricultural drought risks, urban waterlogging, and coastal storm surges faced respectively, in three locations—Ningxia, Wuhan, and Shenzhen—and discusses in-depth the necessity of promoting CRI.

- Based on a Triple Dividend (i.e., avoid damage loss, economic benefit, and social and environmental benefit) framework, this report systematically analyzes the return on investment of three types of CRI—namely water-saving irrigation facilities, sponge city construction, and green-grey sea dike construction—in the three case study areas. Our estimate suggests that every RMB 1 invested can generate RMB 2—20 of returns over a period of 30 years.

- Scaling up CRI more broadly in China is extremely important. For instance, the adoption of water-saving irrigation facilities nationwide can ensure national food security; sponge city construction can protect inland cities against stormwater damage; and green-grey sea dike protection can strengthen coastal resilience and protect coastal populations against storm surges.

- China faces significant financial shortfalls for CRI. We must quickly fill the annual funding gap of nearly RMB 500 billion over the next five years, by leveraging private capital and developing new financing mechanisms.

- The three case studies suggest that innovative financial instruments—such as Resilience Bonds (RB), Public-Private Partnerships (PPPs), and Resilience Impact Bonds (RIB)—can create effective new finance streams to fund CRI. Specific financing strategies developed by local governments and financial institutions must be informed by cost-benefit analyses.

Background

In August 2021, the latest report of the Intergovernmental Panel on Climate Change (IPCC) suggests that accelerating global warming has led to irreversible changes to nature and ecosystems (IPCC 2021). To effectively reduce the potential economic losses caused by increasing extreme weather events, all countries, especially developing ones, urgently need to accelerate investment in climate adaptation while enhancing their climate mitigation efforts. The Global Commission on Adaptation's 2019 global flagship report *Adapt Now: A Global Call for Leadership on Climate Resilience* (hereafter referred to as the GCA Flagship Report) states that if the international community does not take immediate action on climate adaptation, climate change and its impacts could depress global agricultural yields by up to 30 percent by 2050; the population lacking access to water will soar from 3.6 billion today to 5.0 billion by 2050; rising sea-level and greater storm surges could displace hundreds of millions of people in coastal cities, which will cost the coastal urban areas more than US$1 trillion each year (GCA 2019).

China is among the countries that are most affected by climate change. It is estimated that under a "worst-case climate change scenario," the frequency of heat waves in China could triple by the end of the 21st century. Water availability could be affected in the arid and semi-arid regions of western China, and the area of drought-affected farmland could increase by more than 2.5 times (Xie et al. 2019). An increase of 1.5°C in global average temperature could lead to $112 billion of direct economic losses from heavy rainfall and flooding in China, four times higher than between 2006 and 2018 (Jiang et al. 2020). Warming temperature and sea-level rise will exacerbate typhoon storm surges in China's coastal areas. Shanghai, for example, could be submerged entirely under an extreme high tide scenario, with total economic losses estimated at round RMB 203.565 billion ($ 31.318 billion) (Yin 2011). Climate change has directly or indirectly caused damage to infrastructure, taking a heavy toll on human life and the economy.

In the face of this grim situation, action on climate adaptation must be undertaken now. However, the international community has lagged in its efforts to address climate adaptation, with commitments to this subject only begun to grow in recent years. In response, the Climate Adaptation Summit in 2021 provided clear guidance and recommended solutions to scaling up climate change adaptation at global scale. Whereas in China, although the Chinese government's first intention to introduce the concept of climate change adaptation could be traced back to *China's Agenda 21* issued in 1994, adaptation policy implementation is still in its infancy. Therefore, China urgently needs to build robust legislative policy and regulatory systems for climate adaptation and develop clearer action plans and jurisdictional or sectoral coordination mechanisms to promote climate adaptation nationwide (Yang and Fu 2018).

Climate adaptation actions involve a wide range of areas that are crucial to human well-being, including food production, natural environment, water resources, cities, and disaster risk management. It is imperative to enhance climate resilience in infrastructure to protect human life and avoid economic losses from climate risks. As one of the founders of the Global Commission on Adaptation and a world-leading infrastructure developer, China must increase its investment in climate-resilient infrastructure (hereafter referred to as CRI) as early as possible to adapt to climate change.

The year 2021 marks the beginning of China's 14th Five-Year Plan and the implementation of China's pledge to peak carbon emissions by 2030 and achieve carbon neutrality by 2060, which represents a critical window of opportunity to manage the climate crisis and move toward a zero-carbon society. Meanwhile, 2021 also marks a crucial juncture for postpandemic economic recovery. China has included the goal of building "New Infrastructure" as an important task listed in the 14th Five-Year Plan. If the action on climate adaptation can be fully incorporated into the investment, planning, and construction of the "New Infrastructure." This will benefit China greatly by avoiding potential damages caused by climate change, while providing new economic development and employment opportunities, protecting the environment, and enhancing people's well-being.

To improve infrastructure resilience to climate change, it is necessary to project future climate risks confronting infrastructure to identify priority areas for building resilience. Meanwhile, some regions in China have invested or plan to invest in CRI. However, the questions remain to be answered as to how effective the investments will be and whether these CRIs are replicable nationwide. In addition, CRIs are large in scale and capital-intensive, requiring longer operation cycles. The financing of these projects becomes a challenge.

To address these issues, our research focuses on analyzing significant climate risks facing China's infrastructure while assessing costs and benefits associated with CRI investment and exploring potential financing instruments and mechanisms that could help leverage finance for CRI. The findings of this study are expected to inform China's *National Climate Change Adaptation Strategy 2035*, and support the acceleration of climate adaptation action across governments at all levels during the 14th Five-Year Plan. This report, as the first of its kind in China, could help equip policymakers and researchers with a concrete research base and a standard methodological framework to advance climate adaptation actions.

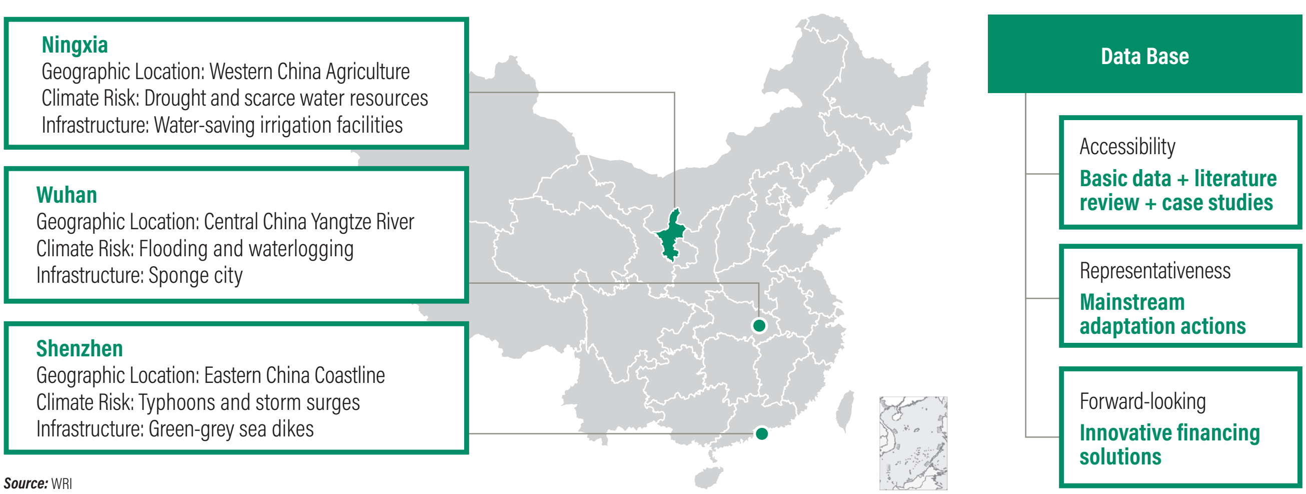
Research Method and Results

Enhancing infrastructure resilience to climate change first requires a comprehensive understanding of climate risk and CRI. The IPCC report defines climate risk as a result of dynamic interactions between climate-related hazards with the exposure and vulnerability of the affected human or ecological system to the hazards (IPCC 2014). Therefore, an analysis of climate risks faced by infrastructures should build upon assessing the exposure and vulnerability of infrastructures to hazards.

In the context of uncontrollable hazards from climate change, reducing exposure and vulnerability is a top priority for enhancing the resilience of infrastructure to climate change. CRI, as mentioned in this research, refers to adding resilience measures to infrastructure throughout the stages of planning, design, construction, and operation to adapt to the changing climate conditions (OECD 2018). The added resilience measures, focusing on reducing infrastructure's exposure and vulnerability to climate-related hazards, would improve the ability of infrastructure to adapt to climate change. In China, the fast economic growth, rapid urbanization, and dense population have increased the exposure and vulnerability of infrastructure to climate hazards.

To project the future climate risks facing China's infrastructure and explore the potential investment benefits and finance innovations for China's CRI, it is necessary to first identify specific climate risks faced by different critical infrastructure systems and the effective protection measures to cope with these risks. Our research focuses on three case studies. The selection of the case study areas takes into account the climate risks with the most frequent and widespread impacts on infrastructure in China as well as the geographic representation and data availability of the study areas (see Figure 1).

Figure 1 | **Selection Criteria for Typical CRI Cases**



Source: WRI

More specifically, we investigate the most relevant CRI in each of the case study areas, including water-saving irrigation facilities to address agricultural drought in Ningxia, sponge city infrastructure to address waterlogging in Wuhan, and green-grey sea dikes to address storm surge in Shenzhen. The three case studies represent three typical climate risks in eastern, central, and western China; cover both rural and urban areas; and involve a wide range of economic sectors, including agriculture, commerce, and industry. It is expected that our analysis in terms of climate risks faced by these representative areas, the expected costs and benefits associated with CRI investment, and the investment and financing mechanisms could provide insights for scaling up CRI across the country.

Modeling the Climate Risks Facing Infrastructure in China

Methodology

Depending on the specific circumstances of each case, different methods are used to project climate risks facing infrastructure in the three regions. In the case of Ningxia and Wuhan, the PRECIS (Providing Regional Climates for Impacts Studies) model is used to project the trends of droughts and floods under two greenhouse gas (GHG) emission concentration scenarios—namely RCP 4.5 and RCP 8.5 by 2050.

PRECIS is a regional climate modeling (RCM) system developed by the Hadley Centre of the UK Met Office (Jones et al. 2004). It can be set up in any region in the world to obtain localized, high-resolution RCP scenarios. Our research focuses on analyzing the climate mean state of Ningxia and Wuhan using the bias-corrected RCM to simulate temperature and precipitation in Ningxia and precipitation in Wuhan.

Whereas in the case of the Shenzhen case study, we estimate the frequency and intensity of storm surge for the Dapeng Peninsula from 2021 to 2050, based on historical hazard data and literature review. The key climate change indicators quantified in the three case studiies are the basis for the cost-benefit analysis that will be conducted later in the research.

Results

Ningxia is a province in northwestern China with limited water access and has historically suffered from chronic drought. Local crop irrigation heavily relies on the Yellow River, and the related agricultural irrigation facilities in Ningxia are extremely vulnerable to changing climate conditions. This research analyzed agricultural drought risks by projecting the future changes of temperature and precipitation in Ningxia under different climate change scenarios, estimated the resulting evapotranspiration, and constructed a relative wetness index as a drought indicator. Our findings suggest that Ningxia will face mild to severe drought risks in different areas in the next 30 years, resulting in depressed crop yields by up to 30 percent. In response, Ningxia needs to enhance the resilience of its agricultural irrigation systems against the increasing drought risks.

Wuhan is a city in central China, located in the transition zone between the southeast coast and the inland. Situated on the Yangtze River, Wuhan also gets abundant rainfall, characterized by a long rainy season and frequent intensive rainstorms. During rainy seasons, the surrounding rivers can easily surge, making it difficult to discharge stormwater and increasing the risk of urban waterlogging. Against this background, this research simulated the changes of two precipitation indicators, namely the rainstorm days and rainstorm intensity. Our findings suggest that the threat of rainstorms facing Wuhan under the RCP4.5 scenario is mainly concentrated in the metropolitan area and its surroundings. Regarding the one under the RCP8.5 scenario, the threat of rainstorms facing Wuhan is aggravated as the rainstorm days and rainstorm intensity in most areas of Wuhan increase. Therefore, the city needs to improve the resilience of its urban drainage systems to cope with waterlogging.

Shenzhen is a city on China's southern coast. Under the governance of Shenzhen municipality, the Dapeng Peninsula is one area that suffers significantly from frequent typhoon landings and storm surges. In recent years, the coastal city has witnessed rapid urbanization and an increasing number of urban infrastructure. Consequently, the coastal ecosystems have been severely damaged, and the exposure of local population and economic losses to marine climate disasters remain at a high level. Building off the existing research and statistics on marine disasters in the area, this research suggests that Dapeng will face accelerated sea-level rises; high tide—level rises; and more frequent, intensive, and long-lasting storm surges under climate change impacts. This will consequently aggravate the damage to coastal infrastructure, disrupt economic activities, damage coastal ecosystems, and threaten people's life. Therefore, building a more climate-resilient coastline is both urgent and necessary.

Cost-Benefit Analysis of CRI Investments

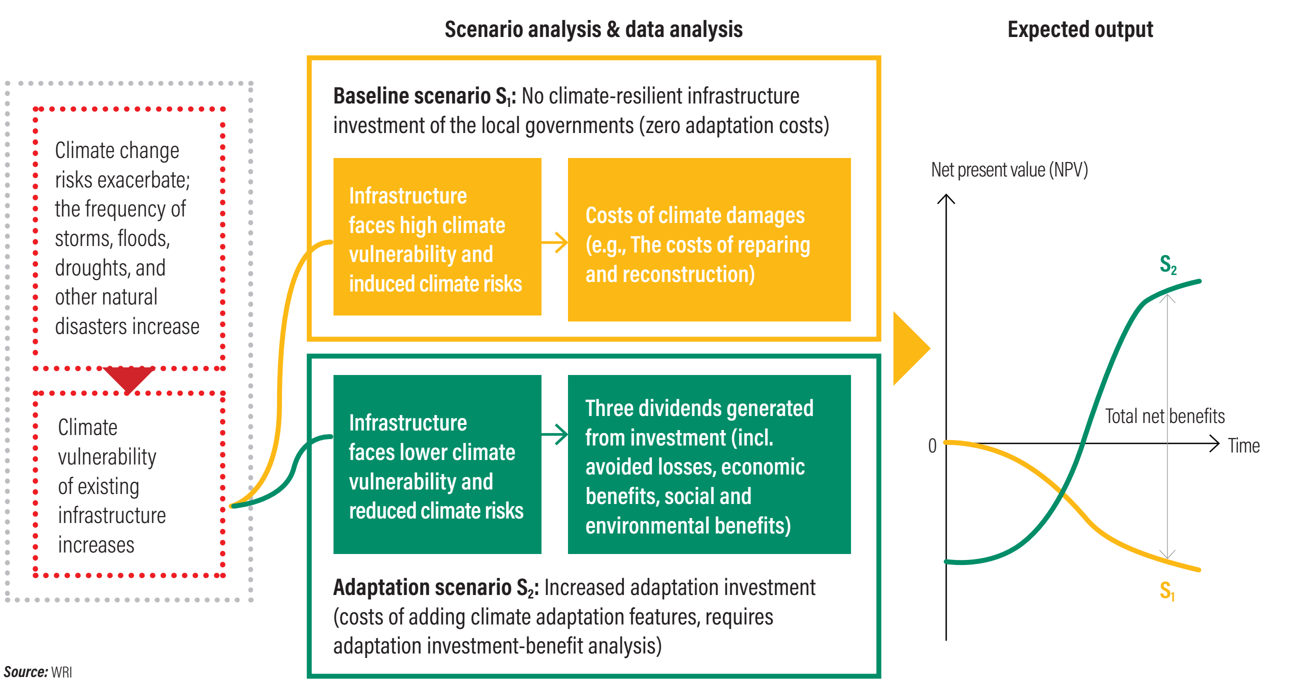
Methodology

The 2019 GCA Flagship Report suggests that adaptation actions could generate triple dividends, namely avoided losses, economic benefits, and social and environmental benefits. The Triple Dividend serves as a useful framework for analyzing the benefits derived from building CRI (GCA 2019; Brandon et al. 2021). Building on the Triple Dividend framework, this research quantifies the benefits of CRI using different economic valuation methods based on the characteristics of the benefits and data availability.

When estimating the costs and benefits of CRI investments, this research classifies the measures that governments may take to mitigate climate risks under two scenarios (see Figure 2), namely a "Baseline scenario S1" and an "Adaptation scenario S2." S1 assumes that local governments will undertake no action toward resilient construction. In other words, there is zero climate adaptation cost. Consequently, in the absence of protection from CRI, climate risks to the existing infrastructure will increase, and so will be direct economic losses in the affected areas as climate change continues to take its toll. S2 assumes that local governments will proactively invest in CRI to mitigate future climate risks. The losses incurred in S1 are avoided as climate risks are reduced for infrastructure equipped with enhanced climate-resilient measures. At the same time, additional resilience measures could bring further economic, social, and environmental benefits.

The costs and benefits of CRI investment are estimated simply by comparing S1 and S2. The costs of CRI investment are mainly the costs of investing in climate-resilient facilities in S2, including specifically the investment in fixed assets and the operation and maintenance costs of climate-resilient facilities over their life cycle. The benefits of CRI investment include the avoidance or reduction of economic losses suffered in the S1 scenario and the postinvestment benefits, including economic, social, and environmental benefits. Considering the uncertainty of climate risks in the long term and the typical life cycle of CRI. This report chooses a period of 30 years (2020—2050) and a 6 percent social

Figure 2 | **Cost-Benefit Analysis Framework for CRI**



Source: WRI

discount rate, which is commonly used for projects of public interest (Ministry of Water Resources of China 2013). Our research measures the net present value and benefit-cost ratios of water-saving irrigation facilities in Ningxia, sponge city infrastructure in Wuhan, and green-grey sea dikes in Shenzhen.

Meanwhile, it uses a 10 percent social discount rate for sensitivity analysis.

Results

- An Overview of Cost-Benefit Analysis by Case Studies

Case 1 | **Ningxia Water-Saving Irrigation Facilities in Response to Drought Risks**[1]

ITEMS		ASSESSMENT METHODS	DATA SOURCES	ASSESSMENT RESULTS
Total costs		Fixed asset investment+ additional annual operation and maintenance costs.	The 13th Five-Year Plan for Water-Saving Improvement in Medium-Sized Irrigation Districts in Ningxia, 2016; the 13th Five-Year Plan for High-Efficiency Water-Saving Irrigation in Ningxia, 2016.	RMB 1.63 billion for the canal renovation project, RMB 12.70 billion for the on-farm water-saving irrigation project.
Benefits				
Avoided losses	Avoided losses of crop yield	Market price method, avoided crop yield losses or crop failure due to the increased risk of drought.	Ningxia climate model projection data; Yang et al. 2009; Wang et al. 2013; Chen et al. 2016; Li et al. 2009; Ningxia Statistical Yearbook 2020; Ningxia Grain and Material Reserve Bureau 2020.	RMB 30—150 million per year for the canal renovation project.
Economic benefits	Water-saving benefits	Shadow pricing method, water right trading scheme allows the additional water saved from the projects for industrial use, and it guarantees the generation of industrial value added to the output of a local industrial sector.	The 13th Five-Year Plan for Water-Saving Improvement in Medium-sized Irrigation Districts in Ningxia, 2016; The 13th Five-Year Plan for High-Efficiency Water-Saving Irrigation in Ningxia, 2016; Ningxia Water Resources Bulletin 2020; Ningxia National Economic and Social Development Statistics Bulletin 2020.	RMB 3.68 billion per year for the canal renovation project.
Economic benefits	Increased crop output	Market price method, benefits of increased crop output from the expanded irrigation area after the canal renovation project is completed.	The 13th Five-Year Plan for Water-Saving Improvement in Medium-Sized Irrigation Districts in Ningxia, 2016.	RMB 52 million per year for the canal renovation project.
Economic benefits	Land-saving benefits	Market price method, benefits from improved land use efficiency within the irrigation areas brought by on-farm water-saving irrigation projects.	The 13th Five-Year Plan for High-Efficiency Water-Saving Irrigation in Ningxia, 2016.	RMB 17 million per year for the on-farm water-saving irrigation project.
Social and environmental benefits	Reduced soil erosion	Replacement cost method, benefits of reduced soil erosion due to the expanded area of vegetation after the canal renovation project is completed.	Zhou et al. 2006; Liang et al. 2016; the 13th Five-Year Plan for Water-Saving Improvement in Medium-Sized Irrigation Districts in Ningxia, 2016; National Bureau of Statistics 2019.	RMB 75,000 per year for the canal renovation project.
Social and environmental benefits	Reduced soil nutrient loss	Replacement cost method, benefits of avoided cropland soil erosion and nutrient loss from the on-farm water-saving irrigation project.	Zhao et al. 2020; Liang et al. 2016; the 13th Five-Year Plan for High-Efficiency Water-Saving Irrigation in Ningxia 2016; Ministry of Agriculture and Rural Affairs 2019.	RMB 60 million per year for the on-farm water-saving irrigation project.
Social and environmental benefits	Boosted carbon sequestration and additional oxygen release	Biomass measurement method, social cost of carbon, and shadow pricing method (for oxygen release), benefits of carbon sequestration and oxygen release from an expanded vegetation area after the canal renovation project is completed.	Shao 2013; Liang et al. 2016; Ma and Li 2019; Results of the Ninth National Forest Inventory of Ningxia Forest Resources 2015; Basic Fact Sheet for Medium-Sized Irrigation Districts in Ningxia; US Government 2021.	RMB 2.90 million per year for the canal renovation project.
Social and environmental benefits	Reduced agricultural pollution	Replacement cost method, benefits of avoided nonpoint source pollution from excessive use of fertilizers and pesticides through water and fertilizer integrated management as part of the on-farm water-saving irrigation project.	Tang et al. 2016; National Bureau of Statistics 2019.	RMB 300 million per year for the on-farm water-saving irrigation project.

Source: WRI

ITEMS		ASSESSMENT METHODS	DATA SOURCES	ASSESSMENT RESULTS
Total costs		Fixed asset investment + additional annual operation and maintenance costs.	Implementation Plan for the Sponge City Pilot in Wuhan; Liang 2018.	RMB 15.19 billion.
Benefits				
Avoided losses	Avoided direct social economic loss	Regression method, sponge city infrastructure facilitates rainwater infiltration and storage and effective control of stormwater runoff, and avoids direct social and economic losses caused by waterlogging.	Wuhan Climate Model Projection Data; Self-Assessment Report on the Performance of Wuhan Sponge City Pilot Projects; Wuhan Third National Agricultural Census-Main Data Bulletin.	RMB 10.01—10.07 million per year.
Economic benefits	Reduced maintenance cost of pipelines	Market price method, sponge city infrastructure increases rainwater infiltration, collection, and storage; relieves the discharge pressure of the municipal pipeline network during rainy seasons; and thus reduces the operation and maintenance costs of the municipal pipeline network.	Wuhan climate model projection data; Self-Assessment Report on the Performance of Wuhan Sponge City Pilot Projects; Sun 2020.	RMB 1.03 million—1.08 million per year.
	Reduced cost of municipal water pollution control	Replacement cost method, green infrastructure reduces stormwater runoff and water pollution, bringing purifying water bodies.	Regulations on the Collection and Use of Sewage Charges; Self-Assessment Report on the Performance of Wuhan Sponge Pilot Projects, 2018.	RMB 10.73 million per year.
	Stormwater recycling benefits	Market price method, rainwater collection facilities recycle and reuse rainwater after purification and treatment, mainly for residents and industry, vegetation watering, road washing, and landscape maintenance.	Self-Assessment Report on the Performance of the Wuhan Sponge City Pilot Projects.	RMB 3.78 million per year.
	Added real estate value	Hedonic pricing method, sponge city infrastructure helps improve the local environment and adds value to the properties.	Jiao et al. 2010; Sun 2020; Provisions on Urban Planning Quota Indicators (Trial); Notice on Further Strengthening the Management of Residential Land Construction Intensity in Wuhan; Wuhan Greening Status Bulletin; Wuhan property prices available on www.anjuke.com.	RMB 30.86 billion per year.
Social and environmental benefits	Benefits of the increased groundwater recharge	Shadow pricing method, green infrastructure increases stormwater infiltration and effectively replenishes groundwater.	Sun 2020; Yan et al. 2019.	RMB 5.00—5.23 million per year.
	Climate regulation benefits	Nonmarket valuation method, benefits from an increased area of grasslands, woodlands, and wetlands from sponge city projects that help regulate regional climate, such as the heat island effect.	Wuhan Sponge City Special Plan; Xie 2015.	RMB 12.33 million.
	Air pollution control benefits	Nonmarket valuation method, as part of the sponge city projects, grassland absorbs pollutants in the air.	Wuhan Sponge City Special Plan; Xie 2015.	RMB 11.14 million.
	Enhanced aesthetic values	Nonmarket valuation method, the nontangible value of natural ecosystems such as grasslands, woodlands, and wetlands in sponge city projects.	Wuhan Sponge City Special Plan; Xie 2015.	RMB 6.00 million.

Source: WRI

Case 3 | **Shenzhen Green-Grey Sea Dikes in Response to Storm Surges**

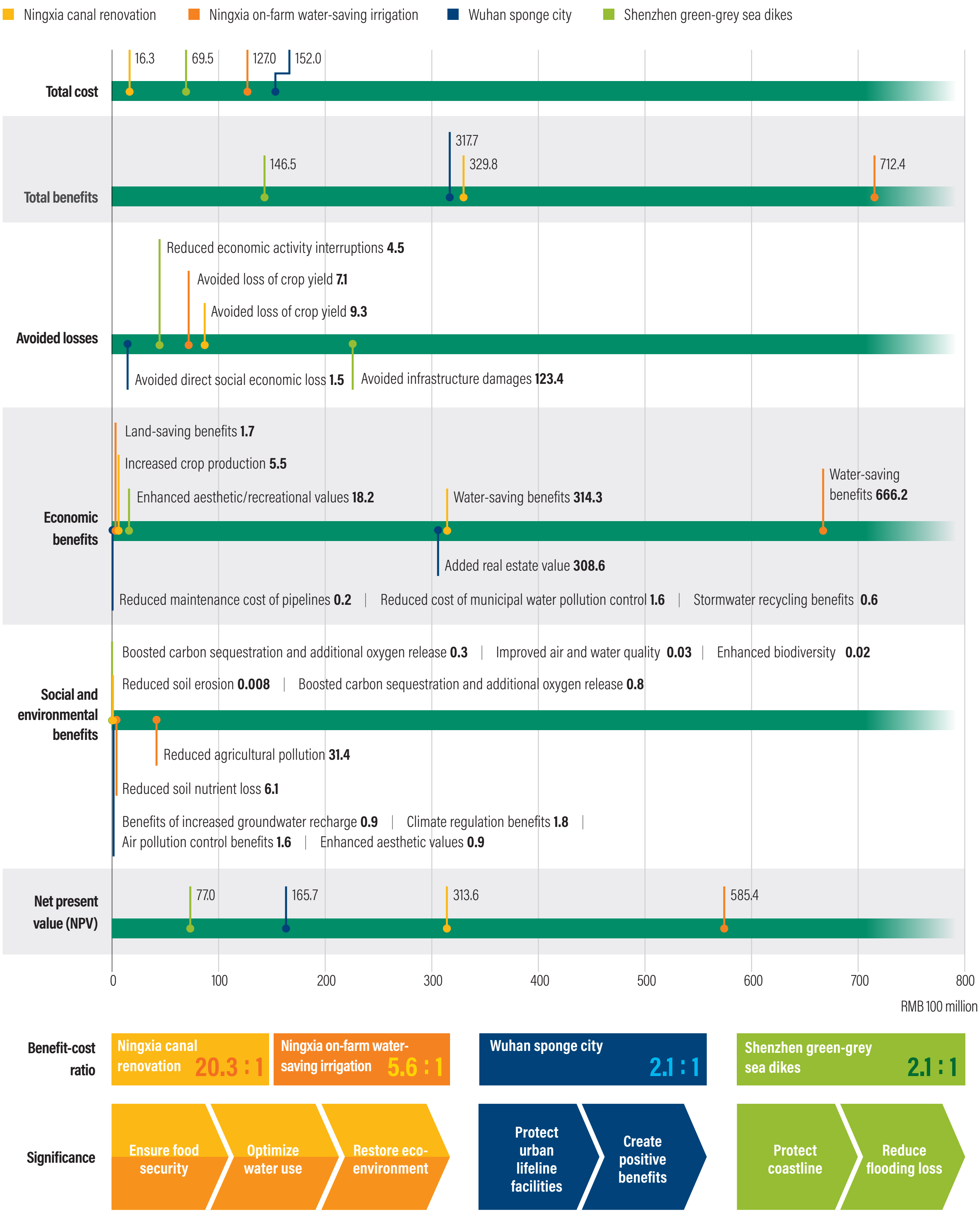
ITEMS		ASSESSMENT METHODS	DATA SOURCES	ASSESSMENT RESULTS
Total costs		Fixed asset investment + additional annual operation and maintenance costs.	The Shenzhen government's budgeting document for the eastern sea dikes reconstruction project.	RMB 8.21 billion.
Benefits				
Avoided losses	Avoided infrastructure damages	Shadow pricing and replacement cost method, avoided infrastructure damage caused by typhoon/storm surges, including fixed asset losses from floods and costs of sea dike reconstruction.	Landsat8 satellite remote sensing data 30*30m on September 22, 2020, data ID:LC81210442020266LGN00; Geospatial Data Cloud GDEMV2 30M resolution digital elevation data; Shenzhen Coastal Zone Comprehensive Protection and Utilization Plan 2018—2035; Statistical Yearbooks for the Dapeng New Zone. 2013—2019; Brief Analysis on Dapeng New Zone's Economic Operation between January and December 2020.	RMB 980 million—2.72 billion per year.
	Reduced economic activity interruptions	Market price method, avoided losses from disruptions to tourism-related economic activities.	Statistical Yearbooks for the Dapeng New Zone 2013—2019; Brief Analysis on Dapeng New Zone's Economic Operation between January and December 2020; Dapeng New Zone's Tourism Industry Performance Report Q3 2018; Tourists Survey in Dapeng 2017.	RMB 39.45 million per year.
Economic benefits	Enhanced recreational values	Travel cost method, the value of recreational uses of the green-grey sea dikes, especially new green infrastructure, which could become a local landmark of tourism attraction.	Tourists Survey in Dapeng 2017; Dapeng New Zone Management Committee-Historic Data of Passengers Reception; other travel costs available on 12306 and other travel websites.	RMB 140 million per year.
Social and environmental benefits	Boosted carbon sequestration and additional oxygen release	The social cost of carbon and shadow pricing method, the value of additional carbon sequestration and oxygen release from restored and expanded mangroves.	Bayraktarov et al. 2016; Zhang et al. 2013; Peng et al. 2016; H. Liang et al. 2016; US Government 2021.	RMB 1.52 million per year.
	Improved air and water quality	Market price method benefits from air and water purification and treatment by green infrastructure such as mangroves.	The decision of the Standing Committee of the Guangdong Provincial People's Congress on the Applicable Tax Amount of Environmental Protection Tax for Air and Water Pollutants in Guangdong Province in 2017; Table of Tax Amount of Environmental Protection Tax; Table of Taxable Pollutants and Equivalent Values; Yu et al. 2009; Chen et al. 2007; Li et al. 2010.	RMB 160,000 per year.
	Enhanced biodiversity	Shannon Wiener's diversity index and nonmarket valuation method, biodiversity enhancement benefits from improved mangrove habitats.	Technical Guidelines on Accounting for Onshore Gross Ecosystem Product (GEP) 1.0; Li et al. 2016; Malik et al. 2019.	RMB 720,000 per year.

Source: WRI

The Cost-Benefit Analysis

Based on a comprehensive analysis, our research suggests that all three cases demonstrate high benefit-cost ratios, ranging from 2.1 to 20.3. For specific categories of benefits for each project and the calculation results, please see Figure 3. The results suggest that the benefits of the Ningxia water-saving irrigation facilities and the Wuhan sponge city infrastructure are mainly derived from economic benefits, while the benefits of the Shenzhen green-grey sea dikes are primarily from avoided losses.

Figure 3 | **The Results of Triple Dividends and Return on Investment Brought by Typical CRI**



Note: In view of the uncertainty of future climate risks, the median values of the calculation range are displayed as the representative results. The canal renovation project in Ningxia's water-saving irrigation program accounted for 23.4% of the total irrigated area of the province, and the on-farm water-saving irrigation project accounted for 19.1% of the total irrigated area. The Wuhan case focuses on Qingshan and Sixin pilot projects; the Shenzhen case focuses on the sea dikes in Dapeng District.

Source: WRI

The three CRI projects selected all generate positive returns on investment. If tailored to local conditions and replicated across the country, they can effectively reduce infrastructure damage caused by climate risks and protect people's lives and property. Ningxia's water-saving irrigation facilities can be built in areas affected by drought, which can safeguard food security and farmers' livelihoods, optimize local water use efficiency, and help restore the regional ecological environment. Among many other economic, social, and environmental benefits, the Wuhan sponge city project, once promoted and built in other inland cities of China, will help protect essential infrastructure for people's livelihood. Also, it will improve the livability of modern cities and contribute to the goal of building a beautiful China. Shenzhen's green-grey sea dikes will not only strengthen the coastline's ability to cope with storm surges and reduce coastal cities' losses from tidal inundation but will also help protect coastal biodiversity and provide opportunities for a low-carbon transition of the local economy.

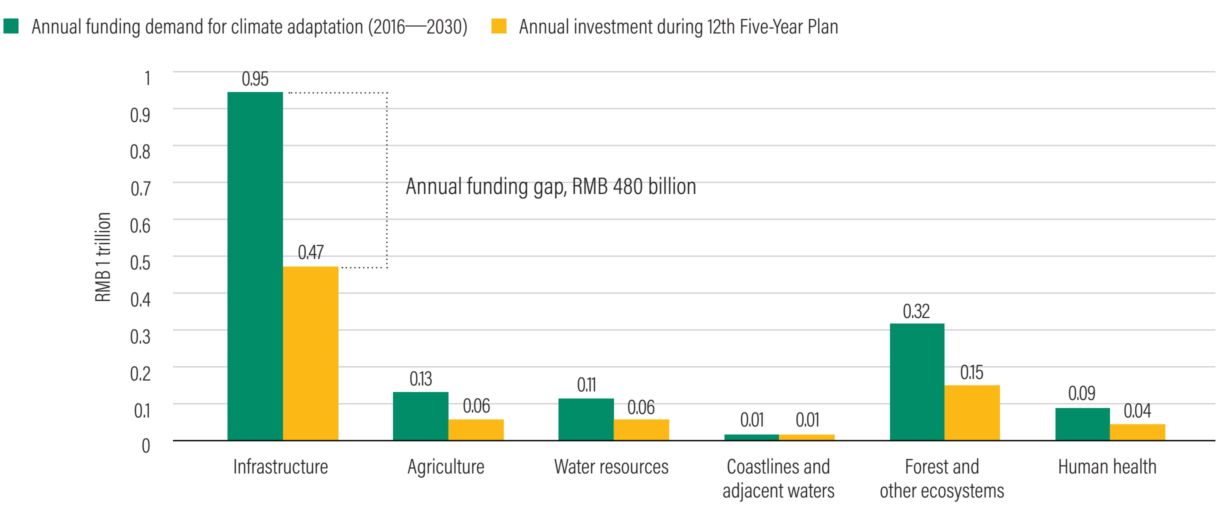
Despite high benefit-cost ratios demonstrated by the three case studies, which are potentially attractive to private capital, the findings in the report have clear caveats. The differences in benefits generated in the three case studies are associated with specific characteristics of infrastructure, and the estimates of the benefits are relatively conservative. Currently, it remains a challenge for existing climate models to estimate the upper limit of the climate risks. As a result, most of the current construction standards for CRI cannot meet the needs for coping with extreme weather events. All these factors are making it increasingly challenging to enable investment in CRI. In addition to avoided losses, CRI can generate significant economic, social, and environmental benefits. If these benefits are transferred to the proper beneficiaries, they will undoubtedly help attract considerable private funding and incentivize financial innovations.

Analysis of Financing Instruments for CRI

Methodology

Building CRI to address increasing climate risks requires sound financial support. However, the world and China fall short in funding. The average funding gap for global infrastructure is about $600 billion per year, and the annual funding gap for climate adaptation is more than $100 billion (Oxford Economic & Global Infrastructure Hub 2021). As CRI carries the characteristics of both, it also faces all challenges of infrastructure investment and climate adaptation. In China, improving the climate resilience of infrastructure will result in an annual funding gap of nearly RMB 500 billion in the next five years (see Figure 4). A large amount of capital investment and effective financing methods are urgently required to alleviate the financial difficulties encountered in the construction of CRI.

Figure 4 | **Adaptation Funding Supply and Demand in China by Sector**



Source: Chai et al. 2019.

To address the financing challenges facing CRI, this research explores innovative financing mechanisms applicable to CRI through a literature review. Drawing on the financing experience from Saïss Water Conservation Project in Morocco, the Green Infrastructure Grant Program of New York City, and the Environmental Impact Bond in Louisiana, this research provides concrete recommendations to the three regions to develop and implement innovative financing mechanisms.

Results

The financing of CRI is still dominated by public finance, with a limited capacity to leverage private capital, and it is urgent to broaden financing channels. The current capital supply mainly comes from the public sector, lacking the participation of the private sector. There are also limited innovative financing instruments to meet the increased financing needs of CRI. Considering specific geographical conditions, the socioeconomic context, and climate risks, this report leverages international experiences to showcase how potential innovative financing mechanisms could help Ningxia, Wuhan, and Shenzhen to increase the funding for their CRI projects.

The Ningxia case study

The water-saving irrigation facilities in Ningxia generate high revenue overall and demonstrate good economic benefits from water saving and increased crop output under future drought risks. However, it remains unclear how these benefits can be translated into tangible investment returns for private investors. Our research recommends that Ningxia collaborate with development and commercial banks to issue Resilience Bonds to attract private capital, which can then be used to provide loans for qualified water-saving irrigation projects. In the meantime, a performance evaluation mechanism should be established to monitor the operation of the fund. Considering that water-saving irrigation facilities require a large amount of fixed investment and have a relatively long operation cycle, the Resilience Bonds alone are not sufficient to provide funding, it is recommended to build an investment fund combining the funds from the public sector and development finance institutions, attract private capital, and raise funds from multiple issuances of Resilience Bonds throughout the operation cycle of the project to close the funding gap for operation and maintenance costs.

The Wuhan case study

The Wuhan sponge city project brings significant economic benefits, avoids losses caused by waterlogging, and generates good social and environmental benefits. The costs of Wuhan sponge city infrastructure are concentrated in the up-front fixed asset investment, while the benefits mainly come from added real estate value and stormwater recycling. Our research recommends that Wuhan develop an incentive mechanism to encourage rainwater collection or create a trust fund that could blend finance from both public and private capital. At the same time, real estate developers are encouraged to incorporate the notion the sponge city into the design and construction of their properties. In addition, the local government of Wuhan can provide subsidies to motivate developers and property owners to build green infrastructure and ensure its long-term operation.

The Shenzhen case study

The primary benefit of the green-grey sea dikes in Dapeng, Shenzhen, comes from the avoided losses. The project is mainly for the public interest, making it difficult to attract private capital. At present, it is entirely funded by the Shenzhen Municipal Government and the Shenzhen Water Affairs Bureau, with little participation from the private sector. Based on the objectives of enhancing coastal restoration, wetland protection, flood control, and freshwater resource protection, Shenzhen could issue Resilient Impact Bonds to leverage private capital and attract investment from businesses and individuals who suffer losses in coastal areas, converting the benefits of avoided losses into project funds. In addition, Shenzhen could use carbon trading mechanisms to turn ecological benefits, such as carbon credit generated from mangrove restoration, into monetary benefits.

Based on the cost-benefit analysis of CRI, this report further examines and analyzes the implementation pathways for governments to promote CRI financing and the decision-making mechanism for finance institutions. As public finance remains the primary funding source for CRI, it creates financial barriers to scale up CRI and meets its full potential. Based on the Triple Dividend framework, it is necessary to identify key beneficiaries of the dividends and optimize the mechanism of converting the benefits into tangible returns for private investors. Regulators and financial institutions should explore and tap into the needs of CRI from all parties, build scientific decision-making and implementation mechanisms, and effectively support the transfer of project benefits.

Challenges and Policy Recommendations for CRI

Based on the above analyses, this report discusses the main challenges facing CRI and the Chinese government's concrete actions to address them (See Table 1). Additionally, China urgently needs to develop a dedicated interministerial coordination mechanism to accelerate the uptake of investment in climate adaptation measures at all levels. This mechanism could support the development of a comprehensive policy system, an evaluation system, and a supervision execution mechanism to advance climate adaptation actions and coordinate between different government levels and departments. Finally, this mechanism could also play a role in facilitating international collaboration, engaging with financial institutions to moblize finance for climate adaptation projects, and building capacity on CRI.

Table 1 | **Challenges Faced by CRI and Policy Recommendations**

	CHALLENGES FACED BY CRI	POLICY RECOMMENDATIONS
Improve our understanding of climate risks	There is a systematic misunderstanding of the differences in climate hazards faced by different types of infrastructures across regions, and a lack of complete databases and methodological frameworks for assessing the relevant climate risks.	• Identify specific climate risks faced by different critical infrastructure systems and integrate climate adaptation into the concept design and implementation of urban and rural planning; • Develop technical standards for CRI; • Strengthen the monitoring and early-warning systems of climate risks and improve the mechanisms to accelerate climate adaptation; • Educate the public about climate risks and improve their ability to cope with them.
Quantify and realize the economic value of CRI	Comprehensive misunderstanding of the economic value and additionality associated with CRI, and a lack of a theoretical foundation for conducting economic valuations and a system for value conversion to inform decisions.	• Develop standard economic valuation frameworks, accounting standards, and audit procedures for CRI projects; • Establish a value conversion system to help fund-raising initiatives for CRI projects.
Accelerate financing for CRI	CRI financing is constrained by limited public finance. It is hard to attract private capital, as most of the benefits provided by CRI are enjoyed by multiple stakeholders, which is difficult to translate into tangible investment returns for private investers. There is insufficient innovation in financial instruments to leverage private capital. The current fiscal system provides more financial and credit constraints.	• Accelerate the establishment of climate-related investment project libraries at both national and local levels, and explore high-quality CRI projects; • Support the research and development of new financing mechanisms to support CRI, and strengthen the disclosure, monitoring, and control of climate risks in various industries; • Encourage local governments to increase fiscal incentives and explore new financing mechanisms that can better leverage private capital.

Source: WRI

ENDNOTES

1. Ningxia's climate-resilient water-saving irrigation program consists of two parts, namely a canal renovation project and an on-farm water-saving project.

REFERENCES

Basic Fact Sheet for Medium-Sized Irrigation Districts in Ningxia, 2021 (in Chinese). 宁夏回族自治区水利厅. 2021. 宁夏中型灌区基本信息表.

Bayraktarov, E., M. I. Saunders, S. Abdullah, M. Mills, J. Beher, H. P. Possingham, P. J. Mumby et al. 2016. The Cost and Feasibility of Marine Coastal Restoration. Ecological Applications 26, no. 4:1055–74, https://doi.org/10.1890/15-1077.

Brandon, C. 2021. Forth coming. The Triple Dividend of Building Climate Resilience: Taking Stock, Moving Forward. Working paper. World Resources Institute.

Brief Analysis on Dapeng New Zone's Economic Operation between January and December. 2020 (in Chinese). 深圳市大鹏新区发展和财政局社会经济调查中心. 2021. 大鹏新区2020年1-12月经济运行简析. http://www.dpxq.gov.cn/sjfb/sjjd/content/post_8542453.html.

Chen, L. 2016 (in Chinese). 陈璐. 2016. 气候变化对宁夏中部干旱带玉米生产影响的模拟研究. 南京: 南京信息工程大学.

Chen, W., H. Hong, L. Zhang, and S. Zhao. 2007 (in Chinese). 陈伟琪, 洪华生, 张珞平, 赵晟. 2007. 中国红树林生态系统服务的能值价值, 资源科学 29, No. 1: 147–54.

Chai, Q., S. Fu, X. Wen, G. Liu, and H. Xu. 2019 (in Chinese). 柴麒敏, 傅莎, 温新元, 刘冠英, 徐华清. 2019. 中国实施2030 年应对气候变化国家自主贡献的资金需求研究. 中国人口·资源与环境, 29 (4) : 1 - 9.

Dapeng New Zone's Tourism Industry Performance Report Q3, 2018 (in Chinese). 深圳市大鹏新区文体旅游局. 2018. 2018年第三季度大鹏新区旅游经济运行情况报告. http://dpxq.gov.cn/xxgk/xxgk/tjsj/tjjb/201811/P020181107337062833843.pdf.

Decision of the Standing Committee of the Guangdong Provincial People's Congress on the Applicable Tax Amount of Environmental Protection Tax for Air and Water Pollutants in Guangdong Province in 2017 (in Chinese). 广东省人民代表大会常务委员会. 2017. 广东省人民代表大会常务委员会关于广东省大气污染物和水污染物环境保护税适用税额的决定.

Global Commission on Adaptation. 2019. Adapt Now: A Global Call for Leadership on Climate Resilience.

Implementation Plan for the Sponge City Pilot in Wuhan (in Chinese). 武汉市人民政府办公厅. 2016. 武汉市海绵城市建设试点工作实施方案.

IPCC. 2014. Climate Change 2014: Impacts, Adaptation and Vulnerability. https://www.ipcc.ch/site/assets/uploads/2018/03/ar5_wgII_spm_zh-1.pdf.

IPCC. 2021. Summary for Policymakers. In Climate Change 2021: The Physical Science Basis.

Jiang, T., B. Su, J. Huang, J. Zhai, J. Xia, H. Tao, T. Wang et al. 2020. Each 0.5°C of Warming Increases Annual Flood Losses in China by More Than US$60 Billion. Bulletin of the American Meteorological Society 101, no. 8: E1464–E1474.

Jiao, L., and Y. Liu. 2010. Geographic Field Model Based Hedonic Valuation of Urban Open Spaces in Wuhan, China. Landscape and Urban Planning 98, no. 1: 47–55. Elsevier BV.

Li, J., K. Yang, N. Cao, Y. Han, and X. Zhang. 2009 (in Chinese). 李剑萍, 杨侃, 曹宁, 韩颖娟, 张学艺. 2009. 气候变化情景下宁夏马铃薯单产变化模拟. 中国农业气象. 30 (03): 407.

Li, Y. 2010 (in Chinese). 李怡, 2010. 广东省沿海防护林综合效益计量与实现研究. 博士学位论文. 北京. 北京林业大学.

Li, H., Y. Peng, J. Liu, S. Wang, and G. Chen. 2016 (in Chinese). 李皓宇, 彭逸生, 刘嘉健, 王树功, 陈桂珠. 粤东沿海红树林物种组成与群落特征. 生态学报. 36, No. 1 (2016):252–60. https://doi.org/10.5846 / stxb201408031548.

Liang, C., S. Xin, W. Dongsheng, Y. Xiuying, and J. Guodong. 2016. The Ecological Benefit–Loss Evaluation in a Riverine Wetland for Hydropower Projects—A Case Study of Xiaolangdi Reservoir in the Yellow River, China. Ecological Engineering 96: 34–44. Elsevier BV.

Liang, H., X. Pan, X. Yu, W. Xu, H. Chen, and X. Li. 2016 (in Chinese). 梁鸿, 潘晓峰, 余欣繁, 许旺, 陈慧明, 李晓科. 2016. 深圳市水生态系统服务功能价值评估. 自然资源学报. 31(9): 1474–87. https://doi.org/10.11849/zrzyxb.20151107.

Liang, X. 2018. Integrated Economic and Financial Analysis of China's Sponge City Program for Water-Resilient Urban Development. Sustainability 10, no. 3: 669. MDPI AG.

Ma, Z. and C. Li. 2019 (in Chinese). 马振华, 李才文. 2019. 西北干旱地区人工造林保存和成林状况影响因素分析. 林业资源管理.

Malik, A., A. Rahim, and U. Sideng. 2019. Biodiversity Assessment of Mangrove Vegetation for the Sustainability of Ecotourism in West Sulawesi, Indonesia. AACL Bioflux 12: 1458–66.

Ministry of Agriculture and Rural Affairs. 2019 (in Chinese). 农业农村部. 2019. 2019年12月鲜活农产品供需形势分析月报 http://202.127.45.101/ztzl/nybrl/rlxx/202001/t20200117_6336178.htm.

Ministry of Water Resources of China. 2013 (in Chinese). 水利部. 2013. 水利建设项目经济评价规范（SL 72-2013）.

National Bureau of Statistics 2019 (in Chinese). 国家统计局. 2019. 分省年度数据. https://data.stats.gov.cn/easyquery.htm?cn=E0103.

Ningxia Grain and Material Reserve Bureau. 2020 (in Chinese). 宁夏回族自治区粮食和物资储备局. 2021. 2020年粮食市场分析.

Ningxia National Economic and Social Development Statistics Bulletin 2020 (in Chinese). 宁夏回族自治区统计局. 2021. 宁夏2020年国民经济和社会发展统计公报.

Ningxia Statistical Yearbook 2020 (in Chinese). 宁夏回族自治区统计局. 2020. 宁夏统计年鉴.

Ningxia Water Resources Bulletin 2020 (in Chinese). 宁夏回族自治区水利厅. 2021. 宁夏水资源公报2020.

Notice on Further Strengthening the Management of Residential Land Construction Intensity in Wuhan (in Chinese). 武汉市自然资源和规划局. 2020. 关于进一步加强武汉市居住用地建设强度管理的通知. http://zrzyhgh.wuhan.gov.cn/zwdt/tzgg/qtgs/202012/t20201228_1571707.shtml.

OECD. 2018. Climate-Resilient Infrastructure, OECD Environment Policy Paper No. 14, OECD Publishing, Paris, http://www.oecd.org/environment/cc/policy-perspectives-climate-resilient-infrastructure.pdf.

Oxford Economic & Global Infrastructure Hub. 2021. Infrastructure Outlook, 25-05-2021 https://outlook.gihub.org.

Peng, C., J. Qian, X. Guo, H. Zhao, N. Hu, Q. Yang, C. Chen, et al. 2016 (in Chinese). 彭聪姣, 钱家炜, 郭旭东, 赵何伟, 胡娜胥, 杨琼, 陈长平等. 2016. 深圳福田红树林植被碳储量和净初级生产力. 应用生态学报. 27: 2059–65.

Provisions on Urban Planning Quota Indicators (Trial) (in Chinese). 国家基本建设委员会. 1980. 城市规划定额指标暂行规定.

Regulations on the Collection and Use of Sewage Charges(in Chinese). 国务院. 2008. 排污费征收使用管理条例（国务院令字第369号）http://www.gov.cn/zhengce/content/2008-03/28/content_5152.htm.

Results of the Ninth National Forest Inventory of Ningxia Forest Resources 2015 (in Chinese). 国家林业局. 2015. 第九次全国森林资源清查宁夏森林资源清查成果（2015年）.

Self-Assessment Report on the Performance of Wuhan Sponge City Pilot Projects (in Chinese). 武汉市人民政府. 2018. 武汉市海绵城市建设示点工作绩效自评报告.

Shao, C. 2013 (in Chinese). 邵传可. 2013. 不同管理模式下人工苜蓿地固碳效应分析. 西安科技大学.

Shenzhen Coastal Zone Comprehensive Protection and Utilization Plan 2018–2035 (in Chinese). 深圳市规划和自然资源局. 2018. 深圳市海岸带综合保护与利用规划（2018–2035）. http://www.sz.gov.cn/cn/xxgk/zfxxgj/ghjh/csgh/zxgh/content/post_1317004.html.

Statistical Yearbooks for the Dapeng New Zone 2013–2019 (in Chinese). 深圳市大鹏新区政府. 2021. 统计年鉴2013–2019. 大鹏新区政府在线. http://www.dpxq.gov.cn/sjfb/tjnjsjfb/index.html.

Sun, W. 2020 (in Chinese). 孙文婧. 2020. 海绵城市建设效益量化及综合评价——以宁夏固原市为例. 西安理工大学.

Tang, K., C. Gong, and D. Wang. 2016. Reduction Potential, Shadow Prices, and Pollution Costs of Agricultural Pollutants In China. Science of the Total Environment 541: 42–50. Elsevier BV.

Table of Tax Amount of Environmental Protection Tax (in Chinese). 中国人大网. 2018. 中华人民共和国环境保护税法-附表一: 环境保护税税目税额表; 附表二:应税污染物和当量值表. http://www.npc.gov.cn/zgrdw/npc/xinwen/2018-11/05/content_2065629.htm.

Table of Taxable Pollutants and Equivalent Values (in Chinese). 中国人大网. 2018. 中华人民共和国环境保护税法-附表一: 环境保护税税目税额表; 附表二:应税污染物和当量值表. http://www.npc.gov.cn/zgrdw/npc/xinwen/2018-11/05/content_2065629.htm.

Technical Guidelines on Accounting for Onshore Gross Ecosystem Product (GEP) 1.0 (in Chinese). 生态环境部环境规划院,中国科学院生态环境研究中心. 2020. 陆地生态系统生产总值（GEP）核算技术指南 1.0版本.

The 13th Five-Year Plan for High-Efficiency Water-Saving Irrigation in Ningxia, 2016 (in Chinese). 宁夏回族自治区水利厅. 2016. 宁夏高效节水灌溉"十三五"规划.

The 13th Five-Year Plan for Water-Saving Improvement in Medium-Sized Irrigation Districts in Ningxia, 2016 (in Chinese). 宁夏回族自治区水利厅. 2016. 宁夏中型灌区节水配套改造 "十三五"规划.

United States Government. 2021. Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990. https://www.whitehouse.gov/wp-content/uploads/2021/02/TechnicalSupportDocument_SocialCostofCarbonMethaneNitrousOxide.pdf.

Wang, L., J. Liu, Q. Li, and R. Qian. 2013 (in Chinese). 王连喜, 刘静, 李琪, 钱蕊. 2013. 气候变化对宁夏水稻的影响及适应性研究. 地球科学进展. 28(11): 1248–56.

Wuhan Greening Status Bulletin (in Chinese). 武汉市园林和林业局. 2021. 2020年武汉市绿化状况公报. http://ylj.wuhan.gov.cn/zwgk/zwxxgkzl_12298/tjxx/lhgb_12361/202104/t20210407_1663095.shtml.

Wuhan Sponge City Special Plan (in Chinese). 武汉市规划研究院. 武汉市海绵城市专项规划. http://www.wpdi.cn/project-3-i_11332.htm.

Wuhan Third National Agricultural Census-Main Data Bulletin (in Chinese). 武汉市统计局. 2018. 武汉市第三次全国农业普查主要数据公报.

Xie, G., C. Zhang, L. Zhang, W. Chen, and S. Li. 2015 (in Chinese). 谢高地, 张彩霞, 张雷明, 陈文辉, 李士美. 2015. 基于单位面积价值当量因子的生态系统服务价值化方法改进. 自然资源学报, 30(08):1243–1254.

Xie, F., Y. Liu, Q. Chao, G. Zhuang, G. Hu, and J. Pan. 2019 (in Chinese). 谢伏瞻, 刘雅鸣, 巢清尘, 庄贵阳, 胡国权, 潘家华. 2019.气候变化绿皮书: 应对气候变化报告. 北京:社会科学文献出版社.

Yan, D., J. Sha, B. Liu, and X. Yang. 2019 (in Chinese). 闫丹丹, 沙金霞, 刘彬, 杨旭洋. 2019. 地下水生态系统服务价值评估. 水电能源科学, 37 (2).

Yang, Q., Y. Xu, E. Lin, W. Xiong, and X. Chen. 2009 (in Chinese). 杨勤, 许吟隆, 林而达, 熊伟, 陈晓光. 2009. 应用 DSSAT 模型预测宁夏春小麦产量演变趋势. 干旱地区农业研究. 27 (2): 41–48.

Yang, X. and L. Fu. 2018 (in Chinese). 杨秀, 付琳. 2018. 国际社会适应气候变化政策机制设计的经验、启示及建议,《气候战略研究》简报 2018 年第 20 期 http://www.ncsc.org.cn/yjcg/dybg/201904/W020190424560175281806.pdf.

Yin, J. 2011 (in Chinese). 殷杰. 2011. 中国沿海台风风暴潮灾害风险评估研究. 华东师范大学. 1: 1–2.

Zhang, L., Z. Guo, and Z. Li. 2013 (in Chinese). 张莉, 郭志华,李志勇. 2013. 红树林湿地碳储量及碳汇研究进展. 应用生态学报. 24 (4): 1153.

Zhao, J., X. Feng, L. Deng, Y. Yang, Z. Zhao, P. Zhao, and C. Peng. 2020. Quantifying the Effects of Vegetation Restorations on the Soil Erosion Export and Nutrient Loss on the Loess Plateau. Frontiers in Plant Science 11. Frontiers Media SA.

Zhou, Z., Z. Shangguan, and D. Zhao. 2006. Modeling Vegetation Coverage and Soil Erosion in the Loess Plateau Area of China. Ecological Modelling 198, no. 1–2: 263–268. Elsevier BV.

Yu, X., C. Li, S. Wang, and M. Peng. 2009 (in Chinese). 于晓玲, 李春强, 王树昌，彭明. 2009. 红树林生态适应性及其在净化水质中的作用. 热带农业工程. 33 (2): 19–23.

ACKNOWLEDGMENTS

There were a lot of experts and colleagues who provided support and invaluable comments in writing and publishing this report. The authors are grateful to the following:

Colleagues from World Resources Institute
Li FANG, Zhe LIU, Xiaoqian JIANG, Shiyong QIU, Lihuan ZHOU, Bo LI, Ruiyun DOU, Jinghan XU, Daiyang ZHANG, and Carter BRANDON.

External experts (sorted by surname)

Jinqiang CHEN	Asia Development Bank
Zhihua CHEN	Division of International Cooperation and Exchanges, Department of Climate Change, Ministry of Ecology and Environment
Qing DAI	Independent consultant
Xiawei LIAO	World Bank Group
Fei XIANG	Liability Insurance Department, PICC Property and Casualty Company Limited
Hongmei XU	National Climate Center
Mingxiang XU	China Institute of Water Resources and Hydropower Research
Yanfei YE	Policy Research Bureau, China Banking and Insurance Regulatory Commission
Stanley YIP	Center for Housing Innovations of the Chinese University of Hong Kong, Centre of Urban Planning & Design of Peking University
Xiang ZHANG	Wuhan University

In addition, we would like to thank Gengtian ZHANG, Director of Urban China Initiative; Fangfang SUN and Mengchan YANG from Shenzhen Academy of Environmental Science; Wenmei HA from Arcadis China; and Zhi CHENG from Ningxia CDM Service Center for their support in collecting data and selecting research methods. We would also like to thank the interns of WRI, they are Meng JIN, Guiqi WANG, Yuli ZHU, Xinyue LIU, and Di LI, for supporting the research work. We are also grateful to Liang XIE for copyediting and proofreading, and Ye ZHANG for publication design and layout.

Last, but certainly not least, we appreciate the Global Commission on Adaptation for funding this research. We are pleased to acknowledge our institutional strategic partners, who provide core funding to WRI: Netherlands Ministry of Foreign Affairs, Royal Danish Ministry of Foreign Affairs, and Swedish International Development Cooperation Agency.

ABOUT THE AUTHORS

World Resources Institute:

Helen DING is a Senior Environmental Economist at Economics Center. Contact: helen.ding@wri.org.

Tian YU is a Junior Economics Analyst at Economics Center. Contact: tian.yu@wri.org.

Wenyi XI is a Research Analyst II at WRI China. Contact: wenyi.xi@wri.org.

Lu LU is a Research Analyst II at WRI China. Contact: lu.lu@wri.org.

Wee Kean FONG is a Deupty Director at WRI China. Contact: weekean.fong@wri.org.

National Center for Climate Change Strategy and International Cooperation:

Ying CAO is a Research Fellow at the Department of Policy and Regulation. Contact: caoying@ncsc.org.cn.

Shuya KUANG is a Research Associate at the Department of Policy and Regulation. Contact: kuangsy@ncsc.org.cn.

International Institute of Green Finance, Central University of Finance and Economics:

Ying CUI is an Assistant Dean. Contact: yingcui@rccef.com.cn.

Jieyu ZHOU is a Research Fellow. Contact: zhoujieyu@iigf.com.cn.

Huixin LIU is a Research Fellow. Contact: liuhuixin@iigf.com.cn.

Institute of Environment and Sustainable Development in Agriculture, Chinese Academy of Agricultural Sciences:

Yinlong XU is a Research Fellow. Contact: xuyinlong@caas.cn.

Kuo LI is a Research Associate. Contact: likuo@caas.cn.

ABOUT WRI

World Resources Institute is a global research organization that turns big ideas into action at the nexus of environment, economic opportunity, and human well-being.

Our Challenge
Natural resources are at the foundation of economic opportunity and human well-being. But today, we are depleting Earth's resources at rates that are not sustainable, endangering economies and people's lives. People depend on clean water, fertile land, healthy forests, and a sTable climate. Livable cities and clean energy are essential for a sustainable planet. We must address these urgent, global challenges this decade.

Our Vision
We envision an equiTable and prosperous planet driven by the wise management of natural resources. We aspire to create a world where the actions of government, business, and communities combine to eliminate poverty and sustain the natural environment for all people.

Our Approach
COUNT IT
We start with data. We conduct independent research and draw on the latest technology to develop new insights and recommendations. Our rigorous analysis identifies risks, unveils opportunities, and informs smart strategies. We focus our efforts on influential and emerging economies where the future of sustainability will be determined.

CHANGE IT
We use our research to influence government policies, business strategies, and civil society action. We test projects with communities, companies, and government agencies to build a strong evidence base. Then, we work with partners to deliver change on the ground that alleviates poverty and strengthens society. We hold ourselves accounTable to ensure that our outcomes will be bold and enduring.

SCALE IT
We don't think small. Once tested, we work with partners to adopt and expand our efforts regionally and globally. We engage with decision-makers to carry out our ideas and elevate our impact. We measure success through government and business actions that improve people's lives and sustain a healthy environment.

ABOUT NCSC

National Center for Climate Change Strategy and International Cooperation (NCSC) is a research institution directly under the Ministry of Ecology and Environment and the main technical support institution of the Department of Climate Change. It is the only national research institution engaged in climate change strategy research and international cooperation in China, and also a window for international cooperation and exchange in China's response to climate change.

NCSC conducts research on climate change policies, regulations, strategies, and planning; undertakes technical support for domestic implementation of conventions, statistical accounting and assessment, management of carbon emissions trading, international negotiations, foreign cooperation and exchanges; carries out dialogue among think tanks, publicity, capacity-building and advisory services addressing climate change; and undertakes management of Clean Development Mechanism projects. As a supporting institution, NCSC participates in the selection, evaluation, and policy research of pilot national low-carbon provinces and cities, low-carbon towns and climate-resilient cities, and provides decision support for China's strategic planning and policymaking in addressing climate change based on its rich research experience and a large number of research results in local actions, practices, and policy systems for addressing climate change.

As a national think tank in climate change strategy research and international cooperation, NCSC has excellent institutional mechanisms and management capabilities in top-level planning and design of major projects, project process management, project fund management, personnel management and results management. In recent years, NCSC has undertaken more than 200 projects of national ministries and international institutions, such as the National Program on Key Basic Research Project (973 Program), the National Science & Technology Pillar Program during the 12th Five-Year Plan Period of the Ministry of Science and Technology, the National Key R&D Program during the 13th Five-year Plan Period of the Ministry of Science and Technology, the Grant Project of China Clean Development Mechanism Fund, and the National Special Fund for Addressing Climate Change. NCSC has successfully performed several management functions of central finance and international projects, such as the China Low Carbon Development Macro Strategy Research Project Office, Office of the Global Center on Adaptation, and Office of the World Bank's PMR Project. It has accumulated rich experience in the construction and operation of large-scale platforms and the management of large-scale projects.

ABOUT IIGF

The International Institute of Green Finance (IIGF) of the Central University of Finance and Economics (CUFE) was established on September 2016 thanks to the donation from Tianfeng Securities. IIGF is first international, independent think tank in China with the mission to promote the development of green finance. With objectives such as "green win-win," "collaborative innovation," and "social service", IIGF believes in high-quality outcomes, independent research, impactful results, and improving society through education. IIGF is a professional scientific think tank with innovative management practices, green finance expertise, and strong network with strategic institutions at home and abroad. IIGF strives to bring about high-level innovation to support greening of the Chinese financial system, sustainable social development, and scientific research in green finance.

IIGF established and continuously expands scientific research in green finance, climate finance, energy finance, and health finance; supports cutting-edge research and promotes interdisciplinary cooperation in high-level international and domestic research projects, while demonstrating impactful, high-level outcomes in the relevant research areas.

Consultation
To leverage expertise in green finance and fulfill organizational mission, IIGF supports policy consultation and regularly provides high-quality policy recommendations to relevant government departments. Additionally, IIGF provides consulting services to financial institutions, public institutions, and enterprises to facilitate implementation of the research outcomes.

Application
IIGF promotes practical research application by transforming research outcomes into innovative financial products. This helps to realize the value of the scientific research and helps to improve innovation capacity of financial institutions and enterprises.

Education
IIGF has been engaged in talent cultivation for many years and has created a relevant talent training system on multiple levels. By setting up high-level and high-quality talent training and incentive mechanisms for students, IIGF contributes to the green transformation of China's economy and whole society.

Dialogue and cooperation
IIGF fosters multilateral, multidisciplinary dialogue between diverse partners though numerous platforms and encourages academics and students working in the green finance to expand the scope of their scientific research.

Communications
IIGF aims to introduce the excellent scientific research outcomes and China's achievements in development of green finance to the international and domestic audience through various communication channels.

FUNDING PARTNERS

GLOBAL COMMISSION ON ADAPTATION

Ministry of Foreign Affairs of the Netherlands

MINISTRY OF FOREIGN AFFAIRS OF DENMARK

Sida

PHOTO CREDITS

Cover 699pic.com; pg. i 699pic.com; pg. 2 699pic.com.

Each World Resources Institute report represents a timely, scholarly treatment of a subject of public concern. WRI takes responsibility for choosing the study topics and guaranteeing its authors and researchers freedom of inquiry. It also solicits and responds to the guidance of advisory panels and expert reviewers. Unless otherwise stated, however, all the interpretation and findings set forth in WRI publications are those of the authors.

WRI CHINA
RM K-M, 7/F, TOWER A, THE EAST GATE PLAZA,
#9 DONGZHONG STREET, BEIJING, CHINA, 100027
PHONE: 86 10 6416 5697
FAX:86 10 6416 7567
WWW.WRI.ORG.CN