Climate Risk Vulnerability Assessment and Management Report

Project number: 48274
July 2017

PRC: Shanxi Urban–Rural Water Source Protection and Environmental Demonstration Project

ABBREVIATIONS

ADB	–	Asian Development Bank
CH_4	–	methane
CO_2	–	carbon dioxide
FSR	–	feasibility study report
GHG	–	greenhouse gas
IPCC	–	Intergovernmental Panel on Climate Change
mm	–	millimeter
N_2O	–	nitrous oxide
PRC	–	People's Republic of China
RCP	–	representative concentration pathway
WWTP	–	wastewater treatment plant

NOTE

In this report, "$" refers to US dollars.

Shanxi Urban–Rural Water Source Protection and Environmental Demonstration Project

Project No. 48274 – PRC

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AECOM Asia Company Limited

July 2017

MAP OF THE PROJECT

Shanxi Urban-Rural Water Source Protection and Environmental Demonstration Project
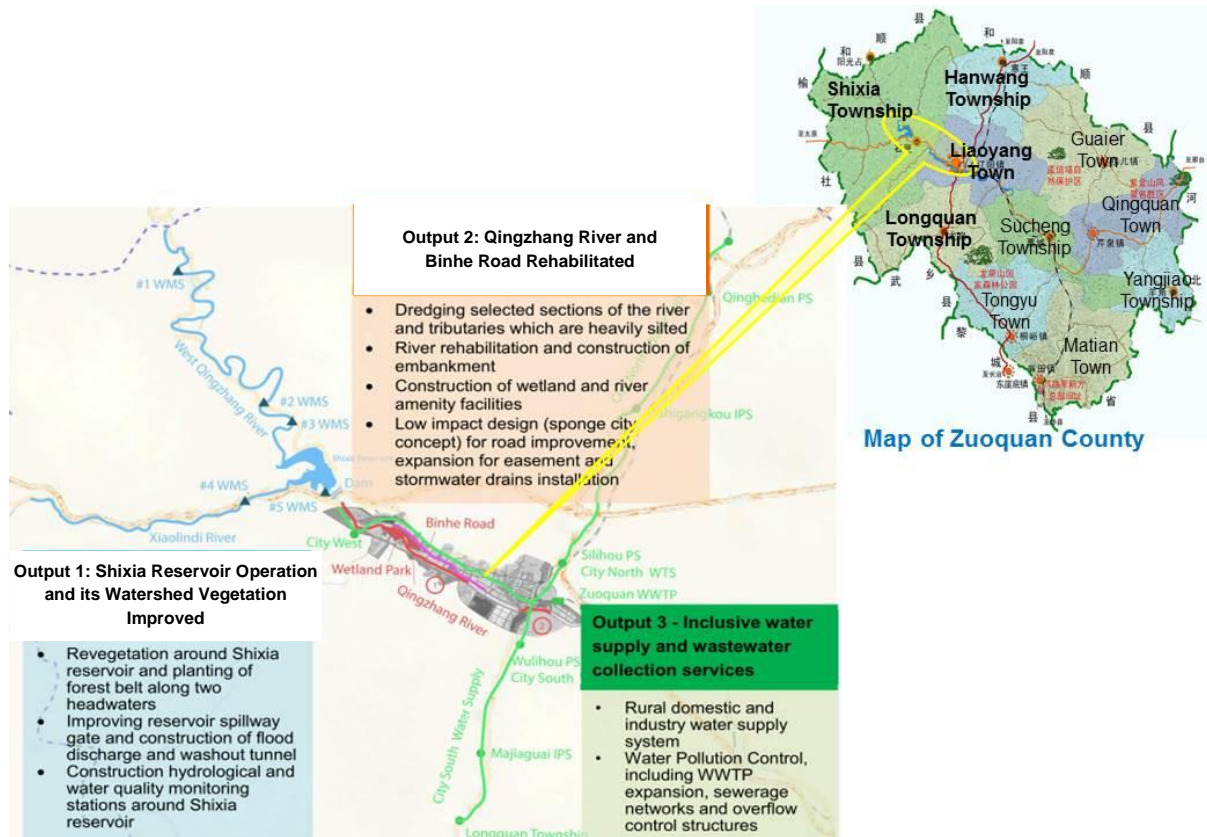
晋中市
Jinzhong Municipality

山西
Shanxi

山西省
Shanxi Province

左权县
Zuoquan County

Zuoquan County

Population: 164,067
Total Area: 2028 ha
GDP: 661 M USD
River Basin: 2000 ha

Location of Zuoquan County

Output 2: Qingzhang River and Binhe Road Rehabilitated

- Dredging selected sections of the river and tributaries which are heavily silted
- River rehabilitation and construction of embankment
- Construction of wetland and river amenity facilities
- Low impact design (sponge city concept) for road improvement, expansion for easement and stormwater drains installation

Map of Zuoquan County

Output 1: Shixia Reservoir Operation and its Watershed Vegetation Improved

- Revegetation around Shixia reservoir and planting of forest belt along two headwaters
- Improving reservoir spillway gate and construction of flood discharge and washout tunnel
- Construction hydrological and water quality monitoring stations around Shixia reservoir

Output 3 - Inclusive water supply and wastewater collection services

- Rural domestic and industry water supply system
- Water Pollution Control, including WWTP expansion, sewerage networks and overflow control structures

Project Site, Outputs, and Components

TABLE OF CONTENTS

1   INTRODUCTION

1.1   Climate and weather is continually changing.

1.   Over the past century, there has been a trend towards increasing global average temperatures. The Fifth Assessment Report (AR5) of the United Nations' Intergovernmental Panel on Climate Change (IPCC) concludes that climate has been undergoing significant changes: the global average temperature of the last century (from 1880 to 2012) has increased by 0.85°C, and the mean average annual temperature for 2003–2012 has increased 0.78°C compared with 1850–1900.[1] Global temperatures are projected to continue rising. Climate change has exerted its influence on the frequency and intensity of natural disasters and become a constraining factor to sustainable regional development.[2] Such change combined with increases in exposure and vulnerability led to increases in economic and property damage, as well as increases in injuries and loss of life.[3]

2.   The People's Republic of China (PRC) is among those countries which are directly affected by climate change. The PRC's vast territories have diverse climates with distinct regional economic characteristics, and there are large economic gaps between regions. Therefore, each region faces differing challenges posed by climate change; and each region must cope in its own way.

1.2   Climate change has already started to cause a wide range of impacts.

3.   The AR5 of the IPCC indicates that climate change has been and will be more relevant to all aspects of natural and social systems. The PRC has already experienced changes in climate, including rising air temperatures and more variable precipitation. Impacts related to climate change are already evident in many regions and sectors. Multiple observations indicate that many natural and biological systems are going through tremendous changes. About 82% of the glaciers are retreating or have vanished since the 1990s based on data from surveys of glaciers.[4] From 1950s to early 2000s, the average sea level has risen by about 1.4–3.2 millimeters per annum (mm/a). Climate changes has been linked to an increased occurrence of flood events in southern PRC and more frequent droughts in northern PRC, which has increased the instability of agricultural activities. The amount of discharge by large rivers in the PRC has decreased since 1950 along with more frequent drought and flood events.[5] The impacts of climate change on the PRC have been profound in the past and will remain so in the future.

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[1] IPCC. 2013. *Summary for Policymakers. In: 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 University Press, Cambridge, UK, and New York, NY, USA, pp. 5.

[2] IPCC. 2012. *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, UK, and New York, NY, USA, pp.29.

[3] United Nations International Strategy for Disaster Reduction (UNISDR). 2009. *Global Assessment Report on Disaster Risk Reduction: Risk and Poverty in a Changing Climate—Invest Today for a Safer Tomorrow*. Geneva, Switzerland. pp.207.

[4] D. Qin and Y. Ding. 2010. Key Issues on Cryospheric Changes, Trends, and Their Impacts. *Advances in Climate Change Research*. 1(1):1-10.

[5] E. Lin, Y. Xu, J. Jiang, et al. 2006. National Assessment Report of Climate Change (II): Climate Changes Impacts and Adaptation. *Advances in Climate Change Research*. 2(2):51-56.

4.   According to current understanding, climate change has had and will have direct or indirect influence on the socioeconomic realms of industry, energy, the economy and human well-being. The PRC's future vulnerability to climate change depends on its choices with respect to sustainable development, and its commitment to increasing climate resilience and incorporating adaptation measures.

1.3   Project Profile

5.   The Zuoquan County in the Jinzhong Municipality is located at the upstream of the Qingzhang River, a main tributary of the Zhang River. The Qingzhang River, together with the Shixia and Xiajiaozhang reservoirs, is a strategic water source for 1.92 million people in six counties of Shanxi Province.

6.   The expected impact of the project will be improved quality of life and environmental sustainability in Zuoquan County. The outcome of the project will be improved living and environmental conditions for urban and rural residents of Zuoquan County. The project will include four major outputs: (i) Shixia Reservoir operation and its watershed vegetation improved, (ii) Qingzhang River and Binhe Road rehabilitated, (iii) inclusive water supply and wastewater collection services achieved, and (iv) institutional capacity strengthened.

1.4   Objective of Climate Change Risk Assessment in this Report

7.   Rising concentrations of greenhouse gases are changing global climate patterns. Warming trends are associated with changes in hydrological systems globally and at the basin scale. These changes include precipitation patterns and extremes; the amount and generation of river flow; the frequency and intensity of flood and drought; and by extension, the quantity and quality of freshwater resources. The magnitude and spatial distribution of changes in climate combined with characteristics of specific basins determine which impacts are the most important in a region.

8.   Climate change impacts the entire water system including water availability, and the efficacy and maintenance of water supply, sewer, and wastewater treatment systems. Climate change impacts that will significantly affect these systems include heat waves, cold events, changing precipitation patterns, and increases in the number of droughts and floods. Because of the long-lived infrastructure involved, it is important to confront and manage the risks of climate change through prudent early planning, management, and investment decisions.[6]

9.   Given the strategic and capital plans of this project, climate change risks will be assessed, including (i) the observed climate change and climate change projections for the future; (ii) the impacts and potential consequence of rising temperatures with related cold and hot extreme weather events, changed precipitation patterns, and more frequent and intense droughts and floods on the water resource protection activities, flood management system, water supply and waste water control system and other project activities; (iii) identify adaptation measures, and assess the appropriateness, efficacy, and costs of adaptation measures; and (iv) based on this assessment, propose potential adaptation options for identified key risks.

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[6] C. Rosenzweig, D.C. Major, K. Demong, et al. 2007. *Managing climate change risks in New York City's water system: assessment and adaptation planning. Mitig Adapt Strat Glob Change*, 12: 1391-1409.

10.   The climate change risk assessment for this project is aimed at (i) using the best science and evidence to understand the potential range of climate change projections that might be faced, and what effects they might have on the project; (ii) improving understanding of vulnerability to current climate risks; (iii) assessing what can be put in place now, and planned for in the future, to increase the resilience of the project; and (iv) minimizing the risk of significant negative climate change impacts.

2   CLIMATE CHANGE IN SHANXI PROVINCE

11.   The "Climate Change Assessment Report for North China, 2013" summarized observed climate change, climate change impacts, and climate change projections for the regional and provincial levels. Key findings concerning climate change in Shanxi Province are primarily based on this report with additional information obtained through literature review.

2.1   Observed Climate Change

12.   Shanxi Province is in the middle latitudes inland with a warm temperate and semi-humid continental monsoon climate zone. Sunshine is relatively abundant in Shanxi, while water shortages are a major limitation to sustainable development in this region. From 1961 to 2010, the annual average temperature was approximately 9.6°C. There was a general increasing trend in annual average temperature in Shanxi Province (annual mean temperature rose from 9.1°C to 10.3°C, Figure 2-1A). The average temperature rise across the province was 0.29°C/10a higher than the national average (Figure 2-1B). During this same period, the average annual total precipitation was approximately 486.6 mm in Shanxi, and per decade this average annual total precipitation ranged from 447.9 mm to 532.9 mm, and declined by 17.7 mm/10a (Figure 2-2).[7] The drought monitoring is based on a meteorological drought index characterized by interdecadal and inter-annual variations. There has been an increasing trend in droughts after 1977 with a continuous dry period until 2008.[8]

13.   Impacts on water resources and agriculture caused by these changes in climate have been observed. Some of these changes have been beneficial over the short run, such as a longer growing season (the increasing trend for no-frost days was about 4.0 days/10a). However, negative climate disturbances to crop production have increased in the past 40 years. The total crop production for maize and wheat experienced slight declines of 5,480 tons/10a. This observed decline in crop production is caused by increased physiological stress due to higher temperatures, insufficient water, severe storms, flooding, the increased incidence of weather extremes and subsequent reduced resilience and/or resistance to insect pests and/or disease. Annual river-flow has decreased slightly, affecting the amount of water available for irrigation.

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[7] {Author}. 2013. *Climate Change Assessment Report for North China. Summary for Policymakers and Summary for Executive. {Name of Publisher}.* Approximate averages and ranges are derived from the graphs included in this report where appropriate and possible.

[8] Zhou J.H., Li L.P., and Qin. A.M. 2010. Study on the determination of meteorological drought index and drought climate changes in Shanxi province. *Agricultural Research in the Arid Areas.* 28(3):240-247.
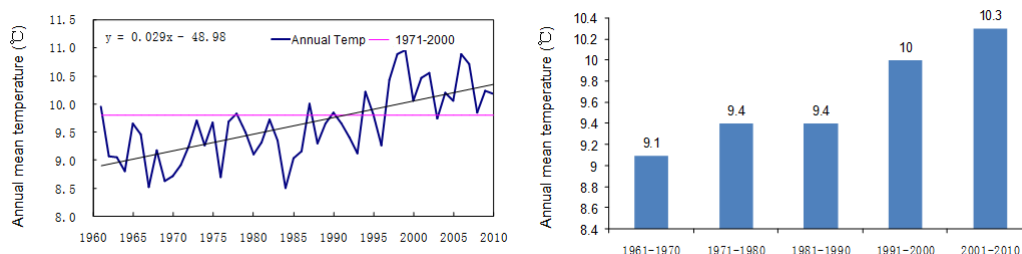
Figure 2-1: The Annual Mean Temperature (Unit: °C)

Note: The dark blue line: annual mean temperature; the pink line: (A) the average annual mean temperature for 1971–2000; the black sloped line: regression line and (B) average decadal temperature in Shanxi Province for the period 1961–2010.
Source: *{Author}.* 2013. *Climate Change Assessment Report for North China. Summary for Policymakers and Summary for Executive. {Name of Publisher}.*
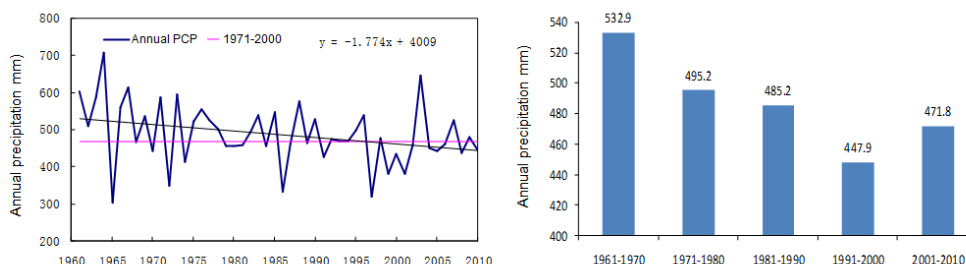

Figure2-2: Average Annual Total Precipitation

Note: The dark blue line: annual total precipitation; the pink line: the average annual total precipitation for 1971–2000; the black sloped line: regression line and average annual precipitation per decade in Shanxi Province for the period 1961–2010
Source: *{Author}.* 2013. *Climate Change Assessment Report for North China. Summary for Policymakers and Summary for Executive. {Name of Publisher}.*

2.2   Climate Change Projections

14.   Climate change projections for Shanxi province are extremely limited, and due to limited time and financial resources, this report focuses on the county level using the Coupled Model Intercomparison Project Phase 5 (CMIP5) data in the next section. Available projections for the province are based on the regional climate model (RegCM3) forcing by FvGCM/CCM3 under SRES A2 showed continuing warming during 2010–2050 for Shanxi Province (Figure 2-3). The annual maximum temperature ranged from approximately 15.5°C–19°C, and increased 0.55°C/10a. The annual minimum temperature ranged from approximately 3.3°C–6.3°C, and increased 0.56°C/10a. The projected average annual total precipitation ranged from approximately 425–875 mm, and increased slightly by 2.5 mm/10a (Figure 2-4), (footnote 7).
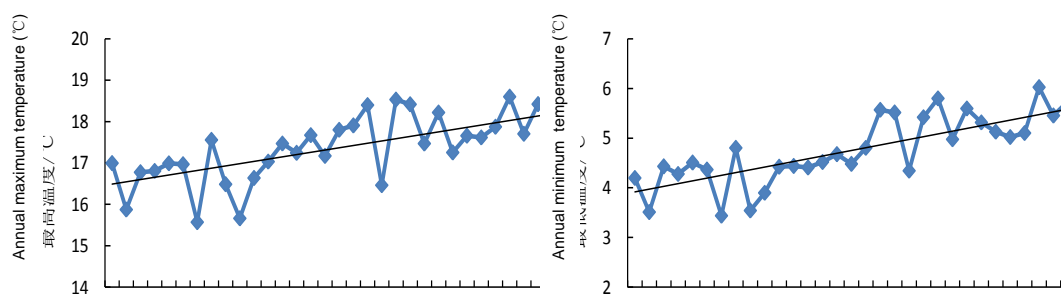
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Figure 2-3: Projected Annual Maximum and Minimum Temperature (°C) by RegCM3 under SRES A2 in Shanxi Province for the Period 2010–2050
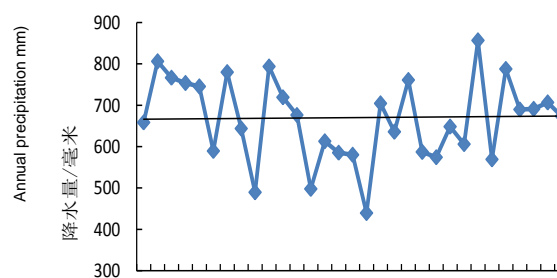

Figure 2-4: Projected Annual Total Precipitation (mm) by RegCM3 under SRES A2 in Shanxi Province for thePeriod 2010–2050

3 OBSERVED CLIMATE CHANGE IN ZUOQUAN COUNTY

3.1 Dataset and Methodology

15. The Zuoquan County meteorological station is the nearest meteorological station with long time-period records for Qingzhang River. Historical climate trends in Qingzhang River were analyzed based on climate observations from this station from 1960 to 2014.

16. The long-term trends for annual precipitation, annual rainfall days, daily rainfall intensity, annual mean temperature, annual maximum temperature, and annual minimum temperature were calculated using the method of linear regression based on data from 1960 to 2014. The changes in precipitation and temperature were analyzed based on annual mean values for 1960–2014 and decadal mean values for the 1960s, 1970s, 1980s, 1990s, and 2000–2014; while changes are relative to the average values from 1961 to 1990. The seasonal pattern changes in temperature were calculated based on the anomalies with decadal means at monthly scale for the same decades. The seasonal pattern changes for precipitation were calculated by comparing the average monthly precipitation for the period 1961–1990 and that of the period 1991–2014.

17. The changes in extreme events, including droughts, storms, heat waves, and cold events, were calculated based on daily precipitation and temperature. In terms of droughts, a meteorological index, the percentage of monthly precipitation anomalies, was used to classify drought categories.[9] The standards of classification of droughts are listed in Table 3.1. In this report, the moderately intensive, intensive, and very intensive droughts were considered. So, the threshold of -60% monthly precipitation anomaly was selected to define drought events; and the likelihood of drought events was calculated as the average number of events in 10 years based on the monthly precipitation from 1960 to 2014. In terms of storms, the days of daily precipitation events greater than 50 mm per year was used to quantify the frequency of extreme storm events; while annual maximum daily precipitation was used to quantify the intensity of extreme storm events. In terms of temperature-related extreme events, cold days (daily mean temperature less than 0°C) and heat waves (daily mean temperature more than 35°C) were analyzed.

Table 3.1: Classification of Drought Levels Based on Monthly Precipitation Anomalies
(GB/T 20481-2006)

Classification of Droughts	Percentage of Monthly Precipitation Anomalies (P_a; %)
None	$(-40)<P_a$
Light	$(-60)<P_a≤(-40)$
Moderately Intensive	$(-80)<P_a≤(-60)$
Intensive	$(-95)<P_a≤(-80)$
Very intensive	$P_a≤(-95)$

Source: {Author}. 2006. *Classification of Meteorological Drought*, (GB/T 20481-2006). Standards Press of China.

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[9] The term 'anomalies' used here and elsewhere means a departure from a reference value or long-term average.

3.2   Observed Historical Trends

3.2.1   Changes in Temperature

18.   The annual mean temperature ranged from approximately 6.5°C–9.3°C; and increased 0.23°C/10a in Zuoquan, which was slightly less than the warming rate in Shanxi Province during 1960–2014 (Figure 3-1A). The annual maximum temperature ranged from approximately 14.0°C–17.4°C, and increased at a warming rate similar to the annual mean temperature (Figure 3-1B). The annual minimum temperature (approximate range from -0.5°C–3.2°C), had the highest warming rate of 0.42°C/10a compared with the annual mean and annual maximum temperature (Figure 3-1C).
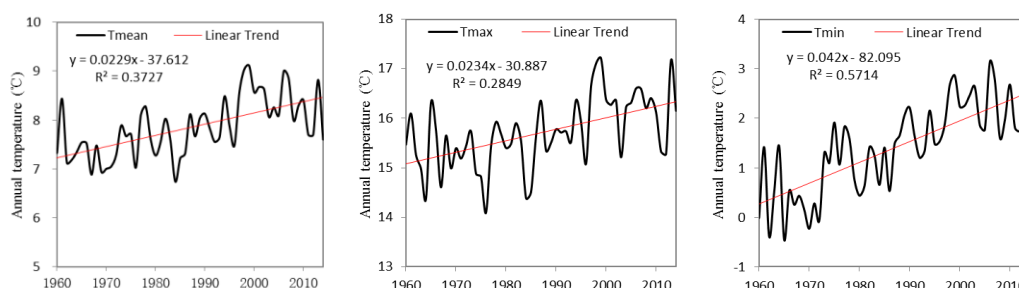

Figure 3-1: Observed Trend of (A) Annual Mean (Tmean), (B) Annual Maximum (Tmax), and (C) Annual Minimum (Tmin) Temperature for Zuoquan for the Period 1960–2014

19.   The changes in annual mean, annual maximum, and annual minimum temperature showed an increasing trend since the 1990s in Zuoquan; while there was no apparent change trend before that. In Figure 3-2, the changes in decadal annual temperature show that there were three cold periods (1960s, 1970s, and 1980s) and two warm periods (1990s and 2000s).
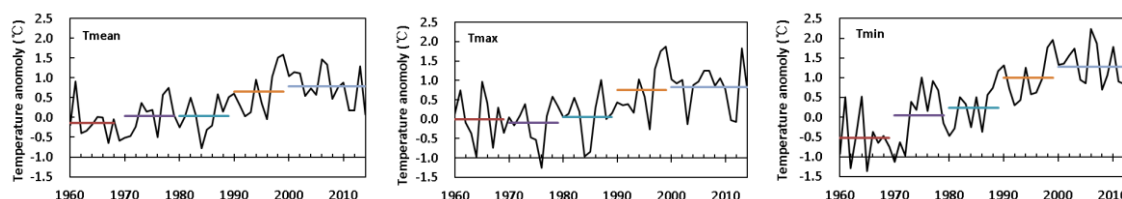
Figure 3-2: Changes in Annual Temperature and Average Decadal Temperature for Zuoquan for the Period 1960–2014

Black line = annual value for 1960s, 1970s, 1980s, 1990s, and 2010–2014; colored line = average decadal value for 1960s, 1970s, 1980s, 1990s, and 2010–2014; Tmax = annual maximum temperature; Tmean = annual mean temperature; Tmin = annual minimum temperature.
Note: Reference period: 1961–1990.

20.   The warming in Zuoquan was characterized by warmer autumns and winters with the largest monthly mean, maximum, and minimum temperature increases in February for the 1990s and 2000s (Figure 3-3).[10]

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[10] Autumn = September, October, and November; winter = December, January, and February; spring = March, April, and May; summer = June, July, and August.

Figure 3-3: Anomalies of Monthly Mean (Tmean), Monthly Maximum (Tmax) and Monthly Minimum (Tmin) Temperature for Zuoquan for the Period 1960–2014

Note: Reference period: 1961–1990.

3.2.2   Changes in Precipitation

21.   The average annual total precipitation was 523 mm during the period 1960–2014; with fluctuations in annual precipitation with a slight decreasing trend. The average annual numbers of days with precipitation was 81.6 days. There was a decreasing trend (-1.5 day/10a) in the annual total number of rain days, while there was no clear trend in the fluctuations in the intensity of daily mean precipitation (Figure 3-4).
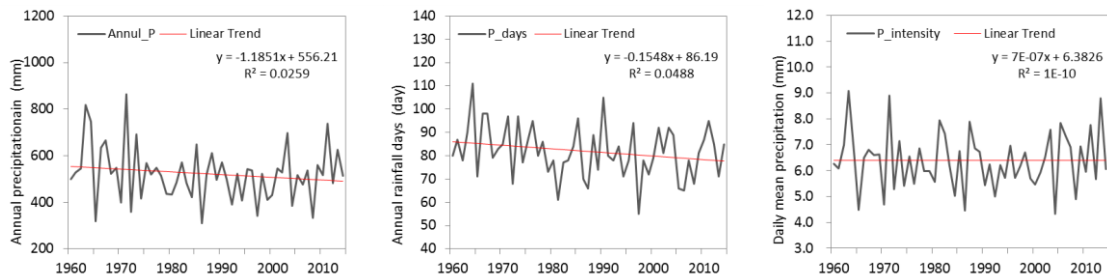
Figure 3-4: Observed Trend of Annual Precipitation (Annual_P), Annual Rainfall Days (P_days), and Daily Mean Precipitation (P_ intensity) for Zuoquan for the Period 1960–2014

22.   The changes in decadal precipitation showed that there were two dry periods (1980s and 1990s) with the decadal precipitation 41.8 mm and 65.9 mm less than the average precipitation from 1961 to1990, and one wet period (1960s) with decadal precipitation 42.8 mm greater than the average precipitation from 1961 to 1990. There is an increase in decadal precipitation from 2000 to 2014. However, the average decadal precipitation was still 14.1 mm less than the average precipitation from 1961 to 1990 (Figure 3-5).
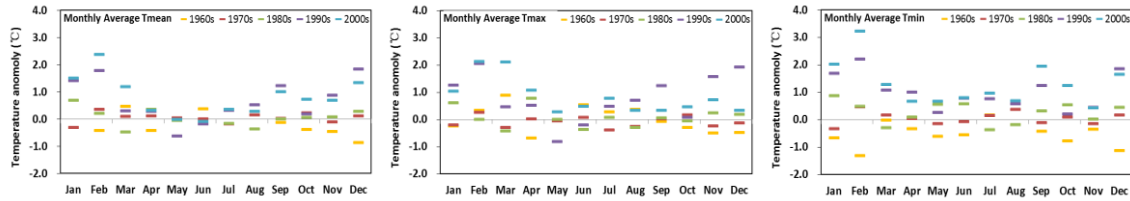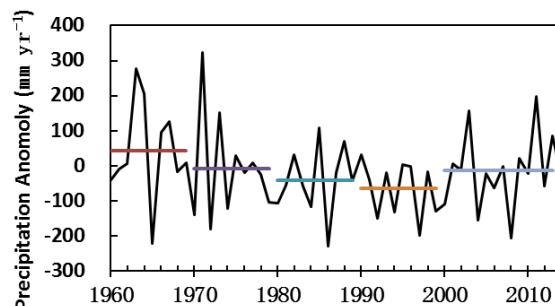
Figure 3-5: Changes in Annual Precipitation for Zuoquan for the Period 1960–2014

Black line = changes in annual precipitation for 1960s, 1970s, 1980s, 1990s, and 2010–2014; and colored line = changes in average decadal precipitation for 1960s, 1970s, 1980s, 1990s and 2010–2014.
Note: Reference period: 1961–1990.

23.   There was a decrease in seasonal precipitation from August to October in 1991–2014 compared with 1961–1990, while greater levels of precipitation for the time frame of 1991–2014 were observed from January–April, and in June and July (Figure 3-6).
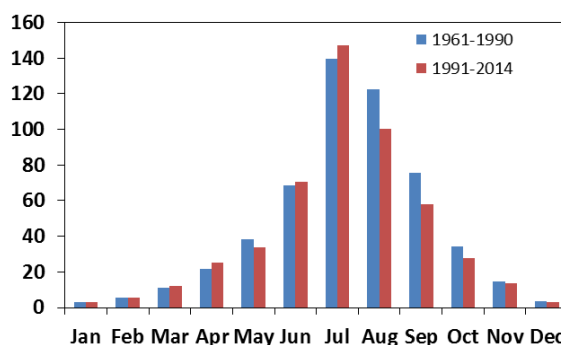
Figure 3-6: Changes in Monthly Precipitation in 1991–2014 compared with Monthly Precipitation in 1961–1990 for Zuoquan

3.2.3   Changes in Drought

24.   The average number of droughts (including moderately intensive, intensive, and very intensive droughts) was 29.2 from 1961 to 1990. The likelihood of drought events showed an increasing trend with a slope of 4.8% from 1960 to 2014. There were severe droughts in the 1980s and 1990s. The number of droughts decreased subsequently, with fewer droughts in 2000–2014 compared to the 1980s and 1990s. However, there were more droughts than in the 1960s and 1970s (Figure 3-7).
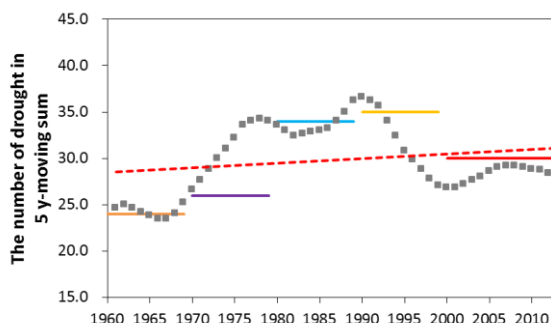
Figure: 3-7 Trend of the Moving-Average Number of Droughts for Zuoquan for the Period 1960–2014

Colored solid lines = numbers of average decadal droughts for 1960s, 1970s, 1980s, 1990s, and 2010–2014; sloped dot line = regression line.

3.2.4 Changes in Storms

25.   The total annual storm events (with daily precipitation greater than 50 mm) for Zuoquan were 40 days for 1960–2014, with three storm events in 1963 and 1987 respectively, and two storm events in 1966, 1971, 1981, and 2001 respectively. The annual maximum daily precipitation varied from 21.7 mm to 120.9 mm for 1960–2014, with the daily precipitation 115.7 mm in 15 August 1981, and 120.9 mm in 2 July 2011. There was an increasing trend for annual maximum daily precipitation from 1960 to 2014 (Figure 3-8).

26.   The available data for storm events are highly variable, and there is no clear trend. However, the increasing trend in annual maximum daily mean precipitation could result in more frequent heavy precipitation events and a bigger impact of storms and floods.
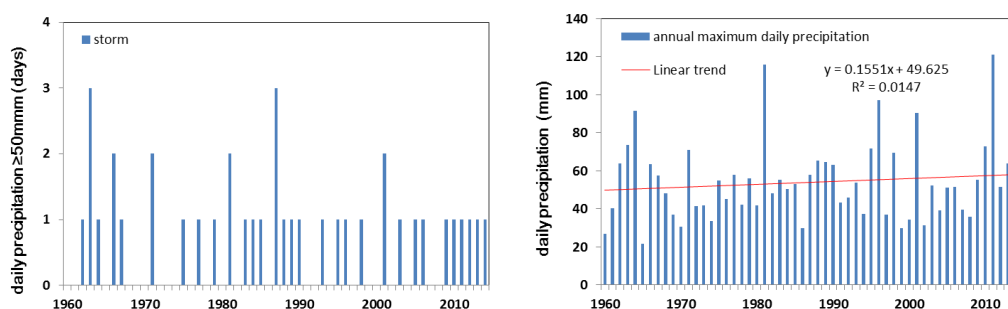
Figure: 3-8 Annual Storm Events (left) and Annual Maximum Daily Mean Precipitation (right) for Zuoquan for the Period 1960–2014

3.2.5 Changes in Temperature-Related Extreme Events

27.   In Zuoquan, climate change is leading to higher temperatures in the winter and reducing the number of days with the temperature lower than 0°C (freeze days). The numbers of days with a daily minimum temperature less than 0°C have decreased by 2.9 days/10a. The average number of freeze days per annum was 109 days for the reference period 1961–1990, while only 100 days after the 1990s (Figure 3-9).

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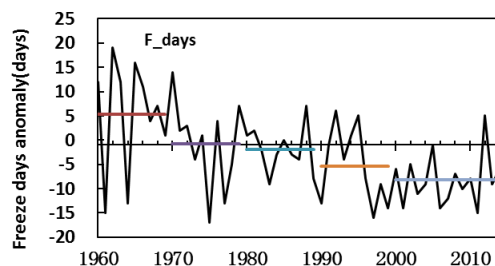
Figure: 3-9 Changes in Freeze Days (F_days) for Zuoquan for the Period 1960–2014

Note: Reference period: 1961–1990.

28.   There were seldom heat waves (daily mean temperature ≥35°C) during the period 1961–1996 for Zuoquan County, with the heat waves occurring more frequently after 1997 (Figure 3-10).
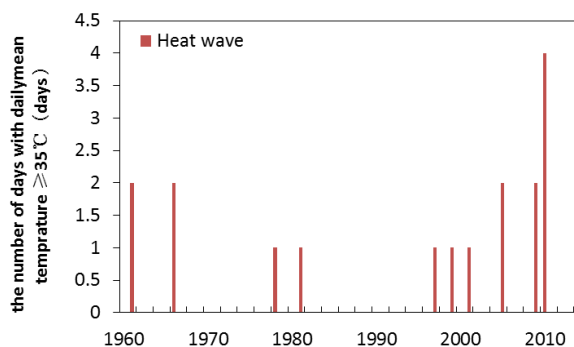
Figure: 3-10: The Number of Heat Waves for Zuoquan from 1960 to 2014

3.3   Summary of Observed Climate Change

29.   The average annual temperature has increased, especially since the late 1980s; and was characterized with warmer autumns and winters, and the substantial warming for annual minimum temperature. The annual total precipitation features no obvious changing trend, but with big annual and decadal variation. Heavy precipitation occurred more frequently. More frequent and intense droughts occurred in the 1980s and 1990s, and have decreased slightly since the 2000s. The numbers of freeze days have decreased, but extreme low temperature events still occur occasionally; while more heat waves occurred after the late 1990s.

4 PROJECTED CLIMATE CHANGE IN ZUOQUAN COUNTY

4.1 Dataset and Methodology

30.	Datasets of climate change projection used in this report were sourced from the Climate Change Projection Dataset in China V3.0. The dataset offers the simple ensemble average results with resolution 1°×1° in China of multiple scenarios under CMIP5. The greenhouse gas emission scenario used in the assessment adopts the new Representative Concentration Pathways (RCPs). The ensemble average projection resulted from the 21 global climate models' (GCMs) simulation of historical climate and future climate change projection under RCP4.5, RCP6.0, and RCP8.5. Projection datasets include the ensemble average and standard deviation of annual and monthly average temperature and precipitation based on the 21 GCMs.

31.	The projected monthly average minimum temperature, monthly average maximum temperature, and monthly total precipitation in four grids surrounding Qingzhang River were used for the climate change analysis. The anomalies of annual mean, annual maximum, and annual minimum temperature; and the annual precipitation were calculated for 2010–2099. Considering the construction period is 2016–2020 for this project, the seasonal pattern changes of temperature and precipitation were calculated for 2021–2050. The period 1986–2005 was used as the baseline for the climate change projection. The period 1986–2005 was widely used as the baseline for the climate change projections in the Working Group I (WGI) AR5 of the IPCC.

4.2 Projected Climate Change

4.2.1 Projected Changes in the Temperature

32.	The annual mean, annual maximum, and annual minimum temperatures in Zuoquan were projected to keep rising under all three RCPs. From 2010 to 2099, the annual mean temperature was projected to rise by 0.36°C/10a, 0.50°C/10a, and 0.80°C/10a respectively under RCP4.5, RCP6.0, and RCP8.5 (Figure 4-1). The average increase in temperature per decade for all three RCPs was higher than the historical increase from 1960 to 2014 for Zuoquan (0.23°C/10a). Moreover, the projections of the RCP6.0 and RCP8.5 scenarios for temperature increases were almost 2.0 times and 3.5 times greater than the historical trends indicated. The annual maximum temperature was projected to rise by 0.40°C/10a, 0.55°C/10a, and 0.91°C/10a respectively under RCP4.5, RCP6.0, and RCP8.5; while the annual minimum temperature was projected to rise by 0.37°C/10a, 0.47°C/10a, and 0.79°C/10a respectively under RCP4.5, RCP6.0, and RCP8.5. The projected increase in the rate of warming was greater for the annual maximum temperature than the projected rates for the annual mean and annual minimum temperatures.
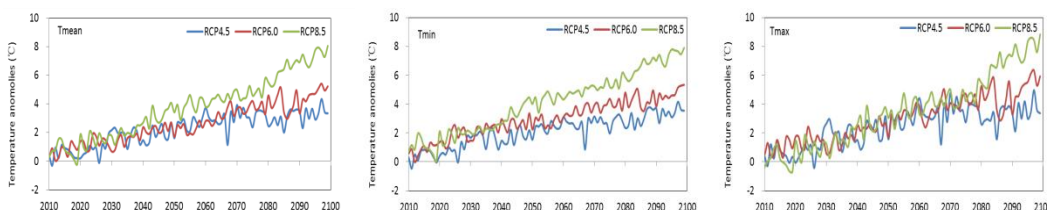

Figure 4-1: Projected Annual Mean, Annual Maximum, and Annual Minimum Temperature Anomalies in Zuoquan for the Period 2010–2099 under RCP4.5, RCP6.0, and RCP8.5
(Baseline: 1986–2005, Unit: °C)

33.   All seasonal temperatures were projected increasing consistently in Zuoquan in the future period 2021–2050 under RCP4.5, RCP6.0, and RCP8.5 for mean, maximum, and minimum temperatures. The increased mean temperature in spring under RCP6.0 and in autumn and winter under RCP8.5 were substantially higher than the projected increases in annual mean temperature. The projected increased maximum temperature in summer under RCP4.5, and that in spring under RCP6.0, and that in summer and autumn under RCP8.5 were generally higher than the projected increases in annual mean temperature. The projected increased minimum temperature in spring under RCP4.5 and RCP6.0, and that in winter under RCP8.5 were generally higher than the increase in annual mean temperature (Table 4.1). The hotter summer (with 2.2°C anomaly higher maximum temperature under RCP6.0), warmer winter (with 3.2°C anomaly higher minimum temperature under RCP8.5), and warmer spring (with 2.3°C anomaly higher mean temperature under RCP6.0) showed an increased probability of heat waves in summer, decreased probability of cold events in winter, and the general warming in spring for 2021–2050 compared with the baseline period of 1985–2006.

Table 4.1: Projected Annual and Seasonal Mean, Maximum, and Minimum Temperature Changes for 2021–2050 under RCP4.5, RCP6.0, and RCP8.5 (Baseline: 1986–2005, Unit: °C)

	Mean Temperature			Maximum Temperature			Minimum Temperature		
	RCP4.5	RCP6.0	RCP8.5	RCP4.5	RCP6.0	RCP8.5	RCP4.5	RCP6.0	RCP8.5
Annual	1.6	1.7	2.3	1.7	1.3	1.8	1.5	2.2	2.6
DJF	1.1	1.4	2.4	1.0	1.0	1.8	1.4	2.2	3.2
MAM	1.7	2.3	2.0	1.5	2.0	1.4	1.7	2.5	2.4
JJA	1.8	1.4	2.2	2.2	1.2	2.0	1.4	2.0	2.2
SON	1.7	1.5	2.4	1.9	1.2	2.1	1.4	2.1	2.6

DJF = December, January, and February, MAM = March, April, and May; JJA = June, July, and August; SON = September, October, and November.

4.2.2   Projected Changes in Precipitation

34.   The precipitation derived from ensemble GCMs was separated into rainfall and snow according to the projected daily temperature (snow: daily mean temperature lower than 0°C; rainfall: daily mean temperature higher than 0°C). The average annual rainfall in Zuoquan is projected to increase by 1.6%, 0.9%, and 2.2% per decade respectively under RCP4.5, RCP6.0, and RCP8.5 for 2010–2099. The average amount of snow is projected to decrease by 1.6%, 2.5%, and 7.8% under RCP4.5, RCP6.0, and RCP8.5, respectively. The variation for both of annual rainfall and snow are very large. The anomalies for annual total precipitation range from -47.4% to 66.1%, -38.8% to 63.1%, and -35.7% to 59% respectively for the three RCPs (Figure 4-2).
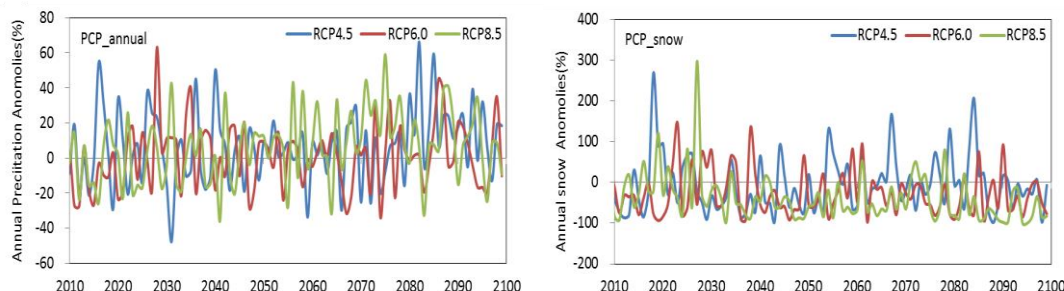
Figure: 4-2 Projected Annual Total Precipitation and Snow Changes in Zuoquan under RCP4.5, RCP6.0, and RCP8.5 for 2010–2099 (Baseline: 1986-2005, Unit: %)

35.   The projected changes in average monthly total precipitation (rainfall and snow combined) for the period 2021–2050 are highly depended on different RCPs which change both in direction and magnitude. However, there were generally increases in average monthly precipitation in October, November, and December; and decreases in June under the three RCPs. The projected changes in average total precipitation in the summer (June, July, and August) showed a decrease for most of the RCPs, except for RCP6.0 in July and RCP4.5 in August (Figure 4-3). The projected decreases for precipitation in summer would imply an increased potential drought risk in the future.
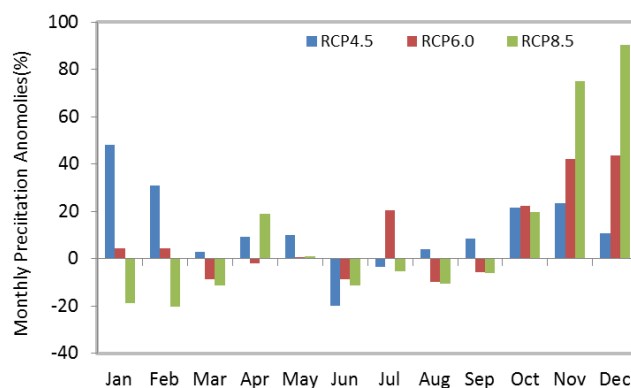
Figure 4-3: Projected Monthly Precipitation Changes in Zuoquan under RCP4.5, RCP6.0, and RCP8.5 for 2021–2050 (Baseline: 1986–2005, Unit: %)

4.3   Summary of Projected Climate Change

36.   The annual average temperature is projected to continue to increase, characterized by the increased probability of heat waves in summer, decreased probability of cold events in winter, and general warming in spring. Annual rainfall is projected to increase slightly while snow decreases; these changes are combined with large inter-annual variations. The uncertainties in projected changes in monthly precipitation are exemplified by the different projections obtained with the three RCPs. There is a consistent increase in precipitation projected from October to December, while all three RCPs project a precipitation decrease in June.

5 POTENTIAL IMPACTS AND RISKS OF CLIMATE CHANGE FOR THE PROJECT ACTIVITIES

5.1 Output 1—Shixia Reservoir Operation and its Watershed Vegetation Improved

37. The subcomponents of Output 1 include (i) re-vegetation around Shixia Reservoir and planting of forest belt along two headwaters; (ii) improving the reservoir spillway gates and construction of flood discharge and washout tunnel; and (iii) constructing five hydrological and water quality monitoring stations.

38. Vegetation recovery and green belt planting will change the land surface and will cause redistribution of precipitation. Re-vegetation and vegetation recovery usually includes conservation of soil and water, flood storage and detention, runoff regulation during dry season, water quality improvement and purification, and microclimate adjustment. The potential impacts of climate change and possible consequences of subprojects are listed in Table 5.1.

Tab. 5.1: Potential Impacts of Climate Change on Water Source Protection Subcomponents

Project	Climate Variables	Potential Impacts	Main Consequences
Vegetation recovery and green belt planting	Increasing temperature	Distribution patterns of pests and diseases may change Plants that are not adapted will be physiologically stressed	Physiologically stressed plants are more susceptible to pests and diseases, will likely have lower productivity and higher mortality rates. This will increase re-vegetation costs, and may lead to increased dredging costs due to increased siltation. Ecosystem benefits, such as the capacity to improve water quality, increase biodiversity, decrease erosion, reduce fire risk, etc. will be decreased.
	Increasing rainfall variability	Increased variability in rainfall may stress plants that are not adapted	Physiologically stressed plants are more susceptible to pests and diseases, will likely have lower productivity and higher mortality rates. This will increase re-vegetation costs, and may lead to increased dredging costs due to increased siltation. Ecosystem benefits, such as the capacity to improve water quality, increase biodiversity, decrease erosion, reduce fire risk, etc. will be decreased.

	Extreme events (high temperature, low temperature, droughts)	Temperature extremes, and prolonged droughts or heavy flooding may stress plants that are not adapted.	Physiologically stressed plants are more susceptible to pests and diseases, will likely have lower productivity and higher mortality rates. This will increase re-vegetation costs, and may lead to increased dredging costs due to increased siltation. Ecosystem benefits, such as the capacity to improve water quality, increase biodiversity, decrease erosion, reduce fire risk, etc. will be decreased.
Newly-built spillway, sluice gate, and flood discharge tunnel	Extreme events (high temperature, low temperature, floods)	Soil freezing and melting will cause soil movement, and potential subsidence. High precipitation levels may exceed capacity of infrastructure.	Stability of foundation may be affected. Infrastructure may require more frequent repair and higher maintenance budgets.
Hydrological monitoring stations and monitoring instruments	Extreme events (floods)	Monitoring equipment may be damaged or lost during a flood event.	Loss or damage of monitoring equipment may reduce the capacity for effective, efficient, and accurate hydrological monitoring. This may increase the repair and maintenance budget for monitoring.

5.2   Output 2—Qingzhang River and Binhe Road Rehabilitated

39.   The sub-components of Output 2 include (i) dredging selected sections of the Qingzhang River; (ii) construction of river embankment; (iii) construction of wetland and river amenity facilities; and (iv) low-impact design for road improvement, bridges, and storm water drains installation based on the sponge city concept to increase resilience. The potential impacts of climate change and possible consequences of sub-projects are listed in Table 5.2.

Tab. 5.2: Potential Impacts of Climate Change on Qingzhang River Subcomponents

Project	Climate Variables	Potential Impacts	Main Consequences
River dredging and river embankment	Extreme events (floods)	Flood peak will increase and there will be increased erosion	Increased erosion into the riverway may result in increased need for dredging. Flood control capacity may be exceeded, and surrounding area will be flooded. This will cause damage to the local economy, physical property, environment (increased pollution) and potentially result in increased illness and loss of life.
	Extreme events (high temperature, low temperature)	Soil freezing and melting will cause soil movement, and potential subsidence.	Embankments may be damaged, and will be less effective at preventing flooding, pollution, and reducing siltation. Infrastructure may require more frequent repair and higher maintenance budgets.
Vegetation and wetland	Increasing temperature	Distribution patterns of pests and diseases may change Plants that are not adapted will be physiologically stressed	Physiologically stressed plants are more susceptible to pests and diseases, will likely have lower productivity and higher mortality rates. This will increase re-vegetation costs, and may lead to increased dredging costs due to increased siltation. Ecosystem benefits, such as the capacity to improve water quality, increase biodiversity, decrease erosion, reduce fire risk, etc. will be decreased.
	Increasing rainfall variability	Increased variability in rainfall may stress plants that are not adapted	Physiologically stressed plants are more susceptible to pests and diseases, will likely have lower productivity and higher mortality rates. This will increase re-vegetation costs, and may lead to increased dredging costs due to increased siltation. Ecosystem benefits, such as the capacity to improve water quality, increase biodiversity, decrease erosion, reduce fire risk, etc. will be decreased.
	Extreme events (high temperature, low temperature, droughts, floods)	Temperature extremes, and prolonged droughts or floods may stress plants that are not adapted (or wash them away).	Physiologically stressed plants are more susceptible to pests and diseases, will likely have lower productivity and higher mortality rates. This will increase re-vegetation costs, and may lead to increased dredging costs due to increased siltation. Ecosystem benefits, such as the capacity to improve water quality, increase biodiversity,

			decrease erosion, reduce fire risk, etc. will be decreased.
Roads and bridges	Increasing temperature, high temperature, droughts, floods)	Chronic high temperatures can degrade road surfaces and building materials.	Foundations and roads may crack, and require more frequent repair and higher maintenance budgets. Infrastructure may also require more frequent repair and higher maintenance budget.
	Extreme events (low temperature, high temperature, droughts, floods)	Roads may be submerged, develop sinkholes, and / or be washed away. Droughts, floods, and soil freezing and melting will cause soil movement.	Traffic may be interrupted, and potentially result in increased injury and loss of life, as well as economic loss, and damage to physical property. Roads and bridges may be damaged, and require more frequent repair and higher maintenance budgets.

5.3 Output 3—Inclusive Water Supply System and Wastewater Collection Services Achieved

40. The subcomponents of Output 3 include (i) rural water supply system including raw water transmission pipelines, rural domestic and industrial water supply; and (ii) water pollution control including Zuoquan County wastewater treatment plant expansion, construction of sewer pipelines, replacement of existing sewer pipelines and reconstruction of overflow manholes. Table 5.3 lists potential climate change impacts on the project for this output.

Table 5.3: Potential Impacts of Climate Change on Water Supply System and Water Pollution Management Subcomponents

Project	Climate Variables	Potential Impacts	Main Consequences
Water resource	Increasing temperature	Increased evapotranspiration	Lowering of reservoir level and reductions in storage water amounts. Less water may be available to meet water demand.
		Increased demand for water to meet daily living requirements, economic development, agriculture, and to maintain the environment.	Water demand increases exceed sustainable water extraction levels, and potentially result in environmental damage (e.g. subsidence, saltwater intrusion, loss of biodiversity, reduction in productivity, etc.), as well as economic loss, particularly in the agriculture sector.
	Extreme events (floods)	Flooding may contaminate water bodies.	Risks to drinking water quality will increase. Costs for treatment may increase. Availability of potable water may decrease.

	Extreme events (droughts)	Reduced water flow into reservoir	Lowering of reservoir level and reductions in storage water amounts. Less water may be available to meet water demand.
		Increased demand for water to meet daily living requirements, economic development, agriculture, and to maintain the environment.	Water demand increases exceed sustainable water extraction levels, and potentially result in environmental damage (e.g. subsidence, saltwater intrusion, loss of biodiversity, reduction in productivity, etc.), as well as economic loss, particularly in the agriculture sector.
Water supply pipe network and pump station	Increasing temperature and extreme high temperature	Accelerated microbial growth in water	Increased water treatment demand; pollution of water supplies; risks to drinking water quality may increase. Availability of potable water may decrease.
		High temperature degrades materials used in infrastructure and equipment of pumping stations.	Infrastructure and equipment aging may be accelerated. This may require more frequent repair and higher maintenance budgets.
	Extreme events (low temperature)	Pipes or joints may be damaged due to soil freezing.	Pipes may crack or joints may leak, leading to water loss. Infrastructure may require more frequent repair and higher maintenance budgets.
	Extreme events (floods)	Pump stations, instruments and facilities may be damaged by floods.	Disruption to water supply system. There may be increased water-borne illness and higher mortality from contaminated water. Infrastructure may require more frequent repair and higher maintenance budgets.
		Increasing turbidity of inflow	Risks to drinking water quality will increase. Costs for treatment may increase. Availability of potable water may decrease.
Wastewater pipe network, separation facilities and wastewater treatment	Increasing temperatures and extreme high temperatures	High temperature degrades materials used in infrastructure and equipment.	Infrastructure and equipment aging may be accelerated. This may require more frequent repair and higher maintenance budgets. Sewage treatment chain may be affected.
		Residential and commercial average daily water consumption and peak water increase.	Sewage volume needing treatment may increase, at an increased cost, and additional wear and tear on equipment. Ecosystem services (water purification, absorption of pollutants) will likely decrease, further increasing treatment cost.

		Increased bacterial regeneration in sewage pipes and treatment facilities.	More treatment effort may be required, requiring higher budget inputs.
	Extreme events (low temperature)	Pipes or joints may be damaged due to soil freezing.	Pipes may crack or joints may leak, leading to water loss. Infrastructure may require more frequent repair and higher maintenance budgets.
	Extreme events (floods)	Surface runoff entering sewage pipes may increase; Flow entering sewage treatment facilities may increase	Maximum carrying capacity of sewage pipes and sewage treatment facilities may be exceeded causing flooding, pollution, property damage, lowered economic productivity, health risks and potential loss of life from subsequent disease.
		Intense rainfalls and floods cause interruption of power supply	Service capacity may be reduced or halted; Contamination accidents may happen due to system shutdown. Service may be interrupted, causing flooding, pollution, property damage, lowered economic productivity, health risks and potential loss of life from subsequent disease.
		Treatment plant and pump station may be damaged by flooding.	Service capacity may be reduced or halted; Contamination accidents may happen due to system shutdown. Service may be interrupted, causing further flooding, pollution, property damage, lowered economic productivity, health risks, and potential loss of life from subsequent disease.

6   POTENTIAL ADAPTION OPTIONS

6.1   General Adaptation Measures

41.   Adaptation is a response to climate change that seeks to reduce the vulnerability of social and biological systems to relatively sudden change and thus offset the effects of climate change. Adaptive capacity is closely linked to social and economic development (IPCC, 2007).

42.   In a literature assessment, Smit et al. (2001) concluded that enhanced adaptive capacity would reduce vulnerability to climate change.[11] In their view, activities that enhance adaptive capacity are essentially equivalent to activities that promote sustainable development. These activities include
  (i)   improving access to resources;
  (ii)   reducing poverty;
  (iii)   lowering inequities of resources and wealth among groups;
  (iv)   improving education and information;
  (v)   improving infrastructure;
  (vi)   improving institutional capacity and efficiency; and
  (vii)   promoting local indigenous practices, knowledge, and experiences.

43.   In this broad sense of climate change adaptation, all the proposed project outputs and components may be considered to reduce vulnerability to climate change, as the project will
  (i)   provide more vegetation and planting around the reservoir and along the river;
  (ii)   improve the reservoir structures and increase its storage capacity;
  (iii)   enhance the flood protection standard of the river;
  (iv)   provide wetland and river amenity facilities;
  (v)   enhance the existing flood warning system;
  (vi)   reduce surface runoff and non-point source pollution by promoting the sponge city design concept;
  (vii)   improve water supply and wastewater collection and treatment; and
  (viii) improve institutional capacity and efficiency.

44.   Notwithstanding the increase in resilience to climate change in Zuoquan provided by the project, the project design has incorporated specific adaptation measures to cater for the adverse impacts due to projected climate change during the life of project. The adaption measures for each project output are linked to the climate risks identified in Chapter 5.

6.2   Climate Change Adaption Options for Output 1—Shixia Reservoir Operation and its Watershed Vegetation Improved

6.2.1   Output 1.1—Revegetation around Shixia Reservoir and Planting of Forest Belt along Two Headwaters

45.   The primary climate risks for this output are reduced productivity and survival of plants stressed by increasing temperatures, extreme high and low temperatures, floods, and droughts.

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[11] Smit, B. (2001). Executive summary. In (book chapter): Adaptation to Climate Change in the Context of Sustainable Development and Equity. In: Climate Change 2001: Impacts, Adaptation and Vulnerability.

46.   Adaptation measures proposed to specifically address these risks include (i) selection of native species which can withstand current and projected future adverse environmental conditions for planting (seeds, seedlings, saplings and cuttings); and (ii) regular inspections of plants to identify outbreaks of disease and insect pests, and provide treatment before they cause significant damage.

47.   Under this output, the Asian Development Bank (ADB) financed $5.67 million for re-vegetation is counted as climate finance (50% for adaptation and 50% for mitigation due to carbon sequestration by plants).

6.2.2 Output 1.2—Improvement of Reservoir Spillway Gate and Construction of Flood Discharge and Washout Tunnel

48.   The primary climate risks are precipitation levels exceeding capacity and infrastructure damage from freeze/thaw cycles leading to soil movement.

49.   Adaptation measures proposed to specifically address these risks include (i) the increase of the spillway sluice gate level by 3 meters (m) to help ensure that capacity is not exceeded (this will also increase reservoir storage capacity under Output 3); (ii) the improvements in reservoir spillway gates and washout tunnel; and (iii) capacity building and training of the operators to conduct regular inspections for climate-related (and other types of) damage to ensure the safety of dam structures.

50.   ADB financed $3.71 million for improving the reservoir spillway gate, construction of the flood discharge and washout tunnel, and increasing the spillway sluice gate level by 3 m are counted as adaptation finance.

6.2.3 Output 1.3—Hydrological and Water Quality Monitoring Station

51.   Damage or loss of equipment from flooding is the primary risk from climate change.

52.   The specific adaptation measure to be taken is careful site location. The stations will be located on high elevations to avoid current and projected future flood zones. This will not incur additional financing costs. The monitoring stations are vital components of the project monitoring for assessing adaptation effectiveness and increasing climate resilience through the early identification of potential problems under multiple outputs below.

53.   ADB financed $1.6 million for equipment is counted as adaptation finance.

6.3   Climate Change Adaption Options for Output 2—Qingzhang River and Binhe Road Rehabilitated

6.3.1   Output 2.1—River Dredging

54.   The primary risk is that increased flooding may increase erosion, and thus siltation of the river bed.

55.   Specific adaptation measures are to monitor vegetation and embankment integrity, and make necessary repairs in a timely fashion. This is already incorporated in the monitoring plan, and should not incur additional financing costs.

6.3.2 Output 2.2—Construction of Embankment

56. The primary climate risks identified include increased river flood peaks overwhelming the embankment from potential heavy precipitation events; and damage to vegetation stabilizing the embankment from extreme weather, floods and droughts.

57. In response to these risks, the local design institute (LDI) carried out a sensitivity test increasing the 1-in-20 year design flow by an additional 15% to check if the river embankment was sufficient. It was noted that a short section of the embankment would be overtopped if such an increase occurred. As a specific adaptation measure to projected increases in precipitation, the LDI increased the height of the embankment to cope with this. The LDI indicated that the budget for increasing the embankment is approximately $20,000.

58. As a specific adaptation measure, native plants for embankment stabilizing will be selected based on their tolerance of current and projected high temperatures, low temperatures, waterlogging, and flooding.

59. Under Output 2.2, $0.020 million of the ADB financing are counted as adaptation funds.

6.3.3 Output 2.3—Construction of Wetland and River Amenity Facilities

60. The primary climate risk is current and projected damage to wetland vegetation from extreme weather, floods, and droughts.

61. Adaptation measures proposed to specifically address these risks include (i) selection of native species which can withstand current and projected future adverse environmental conditions for planting (seeds, seedlings, saplings and cuttings); and (ii) regular inspections of plants to identify outbreaks of disease and insect pests, and provide treatment before they cause significant damage.

62. Under Output 2.3, $0.205 million of the ADB financing are counted as adaptation funds; and $0.205 million are counted as mitigation finance.

6.3.4 Output 2.4—Low-Impact Design for Road Improvement

63. The primary climate risks are from extreme temperatures and increased flooding that damage roads and increase washouts potentially injuring or killing travelers.

64. Specific adaptation measures have been adopted in the design of Binhe Road to respond to these risks. Based on the sponge city concept, low impact features are incorporated in the project design, including permeable paving, open curbs and tree pits, and bio-swale which would effectively capture surface runoff, and reduce flooding from increased precipitation and extreme storms. This would also contribute to Output 3 through increased aquifer recharge rates. In addition, an early warning system will be implemented (warning signs and warning lighting) during extreme weather conditions to warn travelers of dangerous road conditions (these costs are captured under Output 4).

65. Costs for this enhanced ("sponge city") design are estimated at $3.72 million for the ADB-financed portion (extracted from procurement plan package ZQ-WS-W5).

6.4 Climate Change Adaption Options for Output 3—Inclusive Water Supply and Wastewater Collection Services Achieved

6.4.1 Output 3.1, 3.2, and 3.3—Water Supply System

66.   Major climate risks identified include water shortages due to rising temperatures, increased evapotranspiration, and increased drought resulting in increased illness, and insufficient water for socioeconomic needs and economic growth; increased flooding due to increased precipitation and extreme storms can cause infrastructure damage, and water contamination; high temperatures and freeze and/or thaw cycles can result in leakages and may contaminate water, reducing the potable water supply.

67.   Specific adaptation measures to address these risks are (i) the increase of the spillway sluice gate level by 3 m to increase reservoir storage capacity; (ii) the incorporation of sponge city concepts that contribute to increases in the aquifer recharge rate; (iii) careful monitoring of infrastructure for damage and leaks; and (iv) the careful selection of facilities location to avoid current and projected flood zones.

68.   The first two measures are captured under Output 2, and no additional financing is required for the last two measures.

6.4.2 Output 3.4, 3.5, and 3.6—Wastewater System

69.   Potential climate change risks identified include increased precipitation leading to an increase in flow for treatment; and increased flooding of facilities due to increased precipitation and extreme storms causing infrastructure damage, and increased water pollution; high temperatures and freeze and/or thaw cycles can result in leakages and may contaminate soil and water, reducing the potable water supply.

70.   Specific adaptation measures to address these risks include
   (i)   increasing the daily flow variation coefficient of the sewage treatment plant to 1.53 to allow for a higher peak flow for design of the treatment units. In addition, it is proposed to install a new type of flow separation device to accurately control the sewage flow entering the sewage treatment system. Also, the aged sewage pipes will be replaced to reduce inflow of storm water to the sewage system, thus further reducing flooding risk; and
   (ii)   careful monitoring of infrastructure for damage and leaks. (The treatment plant is not located in a current or projected flood zone; hence, no additional financing is required for this adaptation feature).

71.   Costs for the wastewater system that can be attributed to adaptation climate finance are estimated at $2.370 for the ADB-financed portion.

6.4.3 Output 4—Institutional Capacity Strengthened

72.   Major climate change risks to strengthening institutional capacity are considered minimal; however, the identified climate risks (current and projected) pose challenges for policy development and planning.

73.   To increase climate resilience, a number of adaptation measures have been included. These include (i) training and capacity building on the sponge city concept, proper monitoring of

project components, and flood warning systems, including projected increased flooding risks and other climate change impacts; (ii) improvement of the existing flood warning system to respond to increased flooding risk; (iii) increasing integration of the urban-rural water supply in order to insure sustainable extraction rates based on climate change projections; and (iv) an action plan for sponge city design that decreases vulnerability to flooding and other climate risks.

74.   Costs for the institutional strengthening that can be attributed to adaptation climate finance are estimated at $2.860 million for the ADB-financed portion.

6.5   Summary of Climate Change Finance

75.   The estimated finance costs which can be attributed to climate change as per the Guidance Note on Counting Climate Finance at ADB are summarized in Table 6-1 below.

Table 6-1: Climate Change Finance

Output	Budget ($)
Output 1 (i) Revegetation around Shixia reservoir and planting of forest belt along two headwaters (ii) Improvement of reservoir spillway gate and construction of flood discharge and washout tunnel (iii) Hydrology and water quality monitoring stations	2,840,000 (adaptation) 2,840,000 (mitigation) 3,710,000 (adaptation) 1,600,000 (adaptation)
Output 2 (i) Incremental cost of raising of a section of 820m long embankment by 0.3m (ii) Tree, shrubs planting (iii) Low impact ("sponge city") design for road improvement	20,000 (adaptation) 205,000 (adaptation) 205,000 (mitigation) 3,720,000 (adaptation)
Output 3 (j) increasing the daily flow variation coefficient of the sewage treatment plant to 1.53 to allow for a higher peak flow	2,370,000 (adaptation)
Output 4 - Capacity building on (i) improvement of existing flood warning system (ii) integrated urban-rural water supply (iii) sponge city design for city development	2,860,000 (adaptation)
Pro-rated financial charges	1,200,000 (adaptation) 210,000 (mitigation)
Total	**21,770.000** **18,520,000 (adaptation)** **3,250,000 (mitigation)**

6.6   Greenhouse Gas Emissions and Sequestration

76.   Project greenhouse gas (GHG) emissions were estimated for three key sources: (i) methane (CH_4) produced during anaerobic phase of wastewater treatment; (ii) nitrogen dioxide (N_2O) emissions in the wastewater treatment plant's (WWTP) treatment process; and (iii) power usage and fossil fuels and electricity for machinery and vehicles to be built, upgraded, or used by the project, as follows. (The feasibility study report [FSR] provides an estimation of the GHG production from the aerobic phase of the modified A/A/O process in the Zuoquan WWTP. However, this is not accounted for as per IPCC guidelines on "biogenic carbon" accounting.[12])

77.   The methane estimation from the anaerobic phase of wastewater treatment used the US EPA carbon accounting methodology:[13] $CH_4 = Q \times 10^{-6} \times BOD_{in} \times EFF_{OD} \times CF_{CH4} \times [(1-\lambda)(MCF_{ww} \times BG_{CH4})]$,where Q is the wastewater influent flow rate (in cubic meter per day [m^3/d]); BOD_{in} is the inlet BOD_5 (in milligram per liter [mg/L]); EFF_{BOD} is the oxygen demand removal efficiency of the biological treatment unit; CF_{CH4} is the conversion factor for maximum CH_4 generation per unit of oxygen demand (0.5 gram of CH_4 per gram of oxygen demand); MCF_{ww} is the methane correction factor for wastewater treatment unit (0.8 for anaerobic treatment process); BG_{CH4} is the fraction of carbon as CH4 in generated biogas (default is 0.65); and λ is the biomass yield (0.1 for anaerobic treatment process). For Zuoquan wastewater treatment, Q is 5,000 m^3/d; the inlet BOD_5 is 200 mg/L; and $EFF_{BOD} = 0.95$. The total CH_4 emissions are estimated to be around 81.1 tons/year (equivalent[14] to 2,271 tons/year of carbon dioxide equivalent [CO_2e]).

78.   Potential N_2O emissions in the WWTP treatment process. The FSR applies the following formula: $M_{N2O} = Q (TN_{influent} - TN_{effluent}) FNi \times 10^{-3}$, where Q is the influent volume (m^3/d); $TN_{influent}$ and $TN_{effluent}$ is the total nitrogen of influent volume (mg/L); and FNi is an empirical emission factor of N_2O during nitrogen removal. According to the FSR for Zuoquan WWTP, Q is 5,000 m^3/d; $TN_{influent}$ and $TN_{effluent}$ is 60 mg/L and 15 mg/L, respectively; and FNi is 0.035. The total estimated N_2O emissions for the project will be around 2.9 tons/year (equivalent[15] to 768 tons/year CO_2e).

79.   There is no estimation of the GHG emissions from the anaerobic sludge digester, since according to the FSR, the sludge will be dehydrated and disposed of as the filling material for river embankment.

80.   Total resulting GHG emissions from the wastewater treatment component amount to 2,565 CO_2e.

81.   Power usage for machinery to be built, upgraded, or used by the project and power usage for river rehabilitation and wetland were converted to CO_2e using the following formula: $CO_2 = K \times EF$, where K is the annual electricity consumption (kWh/year); and EF is the CO_2 emission factor. Power usage of fossil fuels for vehicles to be used by the project were converted to CO_2e using

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[12] Michiel R. J. D., Sirintornthep T., , Sonia M. M. V.,William I., Craig P., Riitta P., and Can W.. (eds).. 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories. *National Greenhouse Gas Inventories Programme*. Chapter 6: Wastewater Treatment and Discharge. IGES, Japan.

[13] EPA. 2010. *Greenhouse Gas Emissions Estimation for Biogenic Emissions from Selected Source Categories*. RTI International, NC.

[14] CH_4 Global warming potential (GWP) values relative to CO_2: 28 (www.ipcc.ch)

[15] N_2O Global warming potential (GWP) values relative to CO_2: 265 (www.ipcc.ch)

an online calculator.[16] Total estimated emissions for power usage in the project will be around 8,191 tons/year CO_2e.

82.   Based on the calculation above, total estimated emissions for the project will be around 10,589 tons/year CO_2e (Table 6-2).

83.   **Carbon sequestration.** In the PRC, annual carbon sequestration capacity of forest is estimated to be approximately 0.3–12 tons of carbon per hectare (ha) depending on forest type, species, and age, as well as soil, water and weather (average annual sunshine hours, rainfall and temperature). Considering the weather conditions of Shanxi Province combined with the findings of a peer-reviewed paper,[17] the value of 5 tons/ha/year was applied for the calculation of carbon sequestration for the project. It is estimated the project tree and shrub planting (about 128 ha) will achieve 641 tons of carbon sequestration per year (Table 6-2).

Table 6-2: Project Greenhouse Gas Emissions (CO_2e) **and Sequestration** (ton/year)

Item	Unit	As CO_2e
Zuoquan WWTP 5,000 m^3/day (N_2O)	1	768
Zuoquan WWTP 5,000 m^3/day (CH_4)	1	2,271
Vehicles (<10t)–(13,200 km/year)	2	7
Boats	6	21
Reservoir Spillway Gate (kWh/year)	1,000	0.865 ($\approx$1)
Water Supply—pumping and treatment (kWh/year)	7,300,000	6,315
Wastewater treatment (kWh/year)	1,387,000	1,200
River Rehabilitation(kWh/year)	328,500	284
Wetland (kWh/year)	146,000	126
Water Monitoring Stations (kWh/year)	273,750	237
Total Emissions		**11,230**
Tree Planting (ha)	128.2	641
Total Sequestration[2]		**641**
Total Estimated Emissions		**10,589 t/year**

CH_4 = methane, CO2e = carbon dioxide equivalent, ha = hectare, km = kilometer kWh = kilowatt hour, m^3 = cubic meter, N_2O = nitrogen dioxide, t = ton, WWTP = wastewater treatment plant.
 Source: Estimates of unit numbers are from the detailed engineering design report for the project.

[16] Online GHG calculator (www.carbonneutral.com.au)
[17] Lu J L, Liang S L, and Liu J. Study on Estimation of Forest Biomass and Carbon Storage of Shanxi Province. Chinese Agricultural Science Bulletin, 2012, 28(31): 51-56.

6.7 Uncertainty

84.   Observed influences and many key risks in the future come from biophysical impacts of climate change. In addition, there are many observed influences and future risks are the product of a series of complex processes, with climate change only one factor.

85.   Future climate projections are still highly uncertain, with the scale, speed, and time of various climate change impacts unknown. Some basic trends are obvious, however, such as warming and increasing climate variability, etc. Due to the uncertainty, decision makers hesitate when faced with investments of adapting climate change. Therefore, the response to climate change risks largely depends on the understanding and ability of decision makers to accept climate change and their aspiration to take climate change risk assessment and management into development strategies and plans.

86.   In this project, zero-cost or low-cost measures which can slow down risks should be adopted; and further cost–benefit analysis can help to determine the adoption extent of high cost adaptation measures. In the design, construction, and management of the project, targeted climate monitoring, impact and risk assessment, adaptation selection, and climate information gathering carried out according to users' needs will be beneficial to slow down the risks of climate change.