Water Stress Analysis and Recommendations for Water Resources Management in Ningxia

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Executive Summary

Ningxia Hui Autonomous Region (referred to as “Ningxia” below) is one of the most water stressed regions in China; total water resources per capita is only 30% of the national average. Economic development, especially the rapid development of Ningxia’s coal industry, is exacerbating the stress on water resources. The coal industry is an important pillar of Ningxia’s economic growth, it comprised around 50% of Ningxia’s total industrial production in 2012 and was responsible for driving GDP per capita up 3 times between 2005 and 2012. However, such an industrial structure dominated by energy production is characterized by high carbon emissions and high water consumption, which exacts a huge burden on Ningxia’s water resources.

In order to help governments and corporations gain a better understanding of water stress associated with local economic development and its impact on socio-economic development in Ningxia, the World Resources Institute (referred to as “WRI” below) has partnered with the Ningxia Development Research Center, and China Water Risk to analyze water resources profiles, water resources management, and current water use patterns in Ningxia. We applied WRI’s Aqueduct Water Risk Framework to assess Ningxia’s baseline water stress (referred to as “BWS” below) focusing on the development of the local coal industry and its impact on water resources and provided suggestions for better management of Ningxia’s water resources.

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The Exploitation and Utilization of Water Resources and Baseline Water Stress

- Ningxia’s annual precipitation is low and unevenly distributed, resulting in the severe scarcity of local water resources. The Yellow River supplies 90% of water demand. Overall, Ningxia’s water management was relatively poor and its use of water inefficient. Over 70% of the land is subjected to high to extremely high water stress. Water sustainability was 8.2; indicating water resource use was unsustainable.

- The agricultural sector accounts for 90% of Ningxia’s total water withdrawal, but its use of water is inefficient. In 2012, the agricultural irrigation water use coefficient was 0.45, while the national average was 0.51. The growth of the coal industry caused a rapid increase in industrial growth, as well as in water consumption (industrial water consumption rose 48.2%). In 2012 alone, Ningxia used up 95% of its planned total water consumption goal set for 2015, yet it fell short of its goal for coal production by 28%. The high water demand of the coal industry exacerbated competition of freshwater with other water users.

- Climate change may exacerbate water risks in Ningxia. Studies indicate that global warming will reduce water supply from the Yellow River, intensifying the contradiction between water supply and water demand in the Yellow River Basin. Because Ningxia’s main water source is the Yellow River, this will have grave implications for the region.

Water Resources Management and Coal Industry Development

- According to Opinion on Implementing Water Resources Argumentation of Coal Power Bases (Ministry of Water Resources, 2013), Ningdong Base’s report on water resources planning argumentation, which outlines how it will ensure water supply for its development, estimates that it will meet 39% of its industrial water consumption needs from the Yellow River (by transferring water rights) by 2015. This figure will rise to 84% by 2020.

- Ningxia began a pilot program offering water rights transfers in 2002. By June 2013, about 88 million cubic meters of water had been transferred to nine industrial projects. Over the 10 years, corporations such as Shuidonggou Power Plant and Yuanyang Lake Power Plant implemented water saving reconstruction projects, saving 70 million cubic meters of water. In the next step, Ningxia will conduct studies on building water rights trading platforms between farmers and corporations, and within corporations. Studies on branch canal water saving policies, technologies and supporting funds will also be carried out.

Coal Industry Growth and Water Stress

- By the end of 2012, 91.5% of the installed power capacity of coal plants in Ningxia was in areas suffering from acute water shortages. Although power plants using air cooling technologies accounted for 62.8% of the total installed capacity (air cooling helps to reduce a plant’s water consumption), the newly planned coal-fired power plants will trigger further increases in water demand. Taking Ningdong Energy and Chemical Industry Base (referred to as “Ningdong Base” below) for example, its installed coal-fired power capacity will rise 1.9 times by 2015 and 2.9 times by 2020. Using 2010 as the base year, water consumption will rise 1.5 times by 2015 and 2.0 times by 2020. The rapid expansion of coal-fired power is increasing water risks in Ningxia.

- Ningxia’s 12th Five-Year Plan (referred to as “FYP” below) for Energy Development suggested establishing a coal chemical industry base and developing a modern coal-to-chemical industry (including coal-to-liquid and coal-to-olefin) in Ningxia. This would also drive up water demand. By 2015, Ningdong Base’s coal-to-chemical industry will see its water consumption increase 3.1 times its 2011 level and 4.3 times by 2020.

Ningxia has made some progress in industrial and agricultural water conservation. From 2004 to 2012, water consumption per 10,000 yuan of GDP fell from 1,274 cubic meters to 298 cubic meters while water consumption per 10,000 yuan of industrial added value decreased from 173 cubic meters to 55 cubic meters. In 2012, the agricultural irrigation water use coefficient increased 2 percentage points to 0.45 against the value in 2010. From 2000 to 2012, the effective irrigation area in Ningxia increased 23.6%, which helped to lower total agricultural water consumption by 22.6%.
There is huge potential for saving water in the agricultural sector. If the agricultural irrigation water use coefficient increases to 0.48, about 0.19 billion cubic meters a year could be saved in 2012; if the coefficient further increases to the national average of 0.516, the water saving potential could reach 0.34 billion cubic meters per year.

The current water resources fee and water prices do not take into account water scarcity and other factors that influence the real value of water, such as Ningxia’s natural environment, economy, social development and so on. This means that the government is not effectively exploiting price leverage to encourage the different sectors to improve their water conservation practices.

Conclusions and Suggestions

Ningxia should prioritize water conservation, in particular improve the efficiency of agricultural water use

Ningxia’s agricultural water use is comparatively inefficient. Its current agricultural irrigation water use coefficient (0.45 in 2012) is much lower than its 2015 target (0.48) and 2020 target (0.53). In terms of its water conservation work, Ningxia should prioritize encouraging the building of water-saving projects, finding new sources to fund agricultural water-saving projects, adjusting cropping structure and so on. To achieve this they have used a variety of measures such as government support, market guidance and farmer participation. Ningxia must also target the efficiencies of industrial and domestic water use and encourage the adoption of water-efficient equipment and technologies.

Ningxia should incorporate water resources into the energy/coal industry development plan as a restrictive factor; promote sustainable development of the energy/coal industry and the sustainable exploitation and utilization of water resources

The existing policy framework treats water and energy as separate elements in Ningxia. It is essential that energy and water management agencies collaborate more closely to ensure the sustainable development of water resources and energy. Decision makers should treat water as a restrictive factor while drawing up development plans for the energy/coal industry and promote the sustainable development of the industry as well as sustainable exploitation and utilization of water resources.

Ningxia should study water rights transfer and promote a water right trading mechanism

Water right transfer is an effective way to meet the industrial sector’s demand for water as well as help to provide funds for reconstructing agricultural water-saving irrigation. Since a transfer platform between companies and the government has already been set up in Ningxia, the next step is to study water rights trading between corporations and farmers and within corporations. Therefore, Ningxia should invest into research and mechanism design that would establish the best water rights trading mechanism, policies and management system to support water saving in irrigation and trading between corporations.

Ningxia should accelerate the reform of water prices, raise water resource fees, and exploit price leverage to encourage water-saving

Ningxia’s current water rates and water resource fees have been set too low to reflect the real value of water scarcity in terms of water resources. This means that the government is not exploiting price leveraging to encourage better water conservation among the various sectors. Ningxia should raise water resource fees to encourage the industrial sector to conserve more water and accelerate the collection of mining drainage fee so that coal companies are encouraged to reuse mining drainage water and use less fresh water. The monitoring of water consumption and the collection of water resource fees can be improved by installing more and better measuring equipment.

Ningxia should set up the eco-compensation mechanism for the mining sector and start the pilot program on eco-
INTRODUCTION

The Ningxia Hui Autonomous Region (hereafter referred to as Ningxia), one of most water stressed regions in China, is located in the dry northwest of the country (see Box 1). For the past several years, Ningxia’s annual average water resources have been about 1.163 billion cubic meters. In 2012, water resources per capita was 167 cubic meters, that is just 7.7% of the national average (2168 cubic meters). This is much lower than the average per capita of countries such as Iraq and Oman in the Middle East that are exceptionally arid (see Figure 1). The Yellow River feeds Ningxia’s social economy. If we add groundwater and river water then Ningxia’s total usable water is 4.150 billion cubic meters, giving a per capita usable water resources of 641 cubic meters, 30.0% of the national average, and still below the water resources poverty line of 1,000 cubic meters per capita set by the World Bank. Clearly, Ningxia is suffering from a serious water shortage.

Ningxia is one of China’s four areas that are irrigated by gravity flow and one of China’s seven major grain production bases. Agriculture is Ningxia’s biggest consumer of water at 90.0% in 2012 (far higher than the national proportion of 63.6%). However, water use efficiency in the agricultural sector is low; the agricultural irrigation water use coefficient was 0.45 in 2012, lower than the national average. Ningxia is an ecologically vulnerable area and sensitive to climate change. Drought — which can last for 16 months — is the most frequently experienced climatic disaster causing huge losses. In 2011, natural disasters cost Ningxia 1.64 billion yuan; mostly from drought. Water shortage is a big hurdle to Ningxia’s socio-economic sustainable development.

In addition to water consumption by the agricultural sector and by residents, the development of coal industry has aggravated water stress in recent years. Its rich coal resources and the West-East Electricity Transmission Project have driven momentum for the growth of Ningxia’s energy industry and its economic growth. In 2012, the industrial added value contributed 38.0% to Ningxia’s GDP, whereas the energy industry, dominated by the coal sector made up 50.0% of the industrial added value, powering Ningxia’s GDP per capita up to US$6,028 (according to 2012 prices), three times higher than the level in 2005, making it 17th among 31 provinces, autonomous regions and municipalities in China. But Ningxia’s industrial structure is dominated by energy production and this consumes huge amounts of water and discharges high levels of pollution, exacerbating water shortages. Ningxia’s 12th Five-Year Plan (referred to as “FYP” below) has earmarked a 76.3% increase in its coal production by 2015 and with installed capacity to increase by 136.0%, based on 2010 levels. It would also enlarge its coal industry with the coal to chemicals industry. Coal mining, thermal power, coal liquefaction and coal-based olefins, will exert great pressure on water resources. The two toughest challenges to Ningxia’s future growth will likely be water shortages and carbon emissions.

To assist governments and corporations better understand Ningxia’s water stress and how it is affected by the local socio-economic development, the World Resources Institute (referred to as “WRI” below) has partnered with the Ningxia Development Research Center and China Water Risk to analyze water resource profiles, water resource management and current water use patterns in Ningxia. We applied WRI’s Aqueduct Water Risk Framework to assess Ningxia’s baseline water stress (referred to as “BWS” below) and studied how Ningxia’s socio-economic development will affect water resources. The impressive growth of Ningxia’s coal industry will exacerbate water shortages and that will drive competition and aggravate conflicts over access to water between the agricultural, industrial and domestic sectors. This report is part of a series research on Ningxia Water Risk. It will provide a preliminary analysis on how Ningxia’s coal...
industry could affect water resources. It is hoped that this information will be beneficial to decision-makers in better understanding how the economic (energy) development is contributing to water stress as well as providing practical suggestions for better water resources management. We also analyze the effect of various scenarios on Ningxia’s future water stress.

This report is divided into five parts: the first offers an overview of Ningxia’s water stress in the economic and social development arenas and lays out the purposes of this study. The second part uses the current water resources exploitation and utilization and applies WRI’s Aqueduct Water Risk Framework to assess Ningxia’s baseline water stress. We also analyze water use competition patterns of different sectors. In the third part, we apply WRI’s Aqueduct baseline water stress map to analyze Ningxia’s water exploitation and utilization stress and challenges posed by Ningxia’s coal industry. The fourth part focuses on an in-depth analysis of Ningxia’s energy industry, water resources management framework and water management in the coal industry. In the fifth
and final part, we offer suggestions on how to sustainably develop Ningxia’s coal industry and water resources.

**STATUS QUO OF WATER RESOURCES EXPLOITATION AND UTILIZATION AND BASELINE WATER STRESS OF NINGXIA**

**Water Resources of Ningxia**

Major water resources used in Ningxia are surface water, underground water, water transferred from the Yellow River and brackish water. Currently, the region relies on the Yellow River as the main driver for its economic growth. Brackish water is not heavily exploited because of high desalination costs. Also, the South-to-North Water Diversion Project (Western Line) is expected to hydrate the region somewhat in the future, however, environmental issues have caused this project to be suspended for the time being.

**1. Local Water Resources**

Ningxia’s total local water resources have averaged 1.613 billion cubic meters for the past few years\(^\text{20}\). This includes 0.949 billion cubic meters of surface water of which 70% comes from the Jing, Hulu and Qingshui Rivers. If we do not count flood water, brackish water and ecological flow (which could add up to 0.649 billion cubic meters), total usable surface water amounts to 0.30 billion cubic meters\(^\text{21}\); and if we subtract underground water that overlaps with the surface water (0.214 billion cubic meters) then we have underground water resources of 0.150 billion cubic meters \(^\text{22}\).
Ningxia’s water resources are widely distributed both spatially and temporally (including from year to year as well as inter-seasonal). More extreme weather often indicates serious water shortages will follow.

- In the five decades between 1961 and 2010, annual average precipitation of Ningxia has fallen by 28.6 millimeters; climate tendency rate was -5.7 millimeters per decade. Inter-annual precipitation variation is quite marked. In the 1960s, region wide annual average precipitation was about 347.5 millimeters compared with 306.9 millimeters in the new millennium. In Ningxia, 70.0% of total annual precipitation occurred from July till September. Farmers in the region need water for their crops from April till June, when only 15.0% of the annual rainfall occurs, creating a considerable lag between water demand and supply during the busy farming season. This causes intense pressure with other industries also competing for access to water.

- Surface water is more abundant in the south of Ningxia than in the north; while underground water is more abundant in the north than in the south. In 2012, Guyuan, one of the five prefecture-level cities located in the south of Ningxia, had 47.0% of the region’s total surface water resources, while land share was 20.4%; Yinchuan, in the north, had 34.0% of Ningxia’s total groundwater resources and a 14.6% share of the land (see Figure 2).

2. The Yellow River

Ningxia draws 90.0% of its water needs from the Yellow River. The main stream of the Yellow River is a cross-provincial body of water; annually there is about 30.68 billion cubic meters of water that passes through Ningxia in the Yellow River and this is counted as a reservoir of surface water. The central government has set an annual quota for water use for Ningxia from the Yellow River. According to the State Council’s water allocation plan in 1987, the quota was 4 billion cubic meters for Ningxia (3.7 billion cubic meters from the main stream with 0.30 billion cubic meters from the surface water).

3. Brackish Water

Since evaporation is high and precipitation is low, the salinity of Ningxia’s water resources is quite high and the region has a large volume of brackish water. About 0.213 billion cubic meters or 22.0% of surface water and 0.399 billion cubic meters or 17.0% of underground water is brackish. Brackish water can be processed and then used for industrial purposes. This alleviates some of the stress on Ningxia’s freshwater resources.

4. South-to-North Water Diversion Project (Western Line, Under Planning)

The South-to-North Water Diversion Project (Western Line) is a significant strategy to relieve northern China’s water shortage problem. The western branch plans to divert water from the main stream tributaries of the Yangtze River into the upstream of the Yellow River, benefitting dry and landlocked northwestern China including Ningxia. Phase I of the plan proposes pumping 0.2 billion cubic meters of water into rivers along the Lanzhou-Hekou stretch which includes Gansu, Ningxia, Inner Mongolia and the north of Shaanxi by 2020.

Baseline Water Stress of Ningxia

BWS is an important indicator in WRI’s Aqueduct Water Risk Framework to measure the competition for, and the sustainability of, water usage. BWS is the ratio of total water withdrawal to usable water resources. BWS greater than 0.8 indicates an extremely risky situation of intense competition over water resources. An explanation of WRI’s Aqueduct BWS can be found in the Appendix.

Figure 2 | Water Resources of Ningxia’s Prefecture-Level Cities

Note: the outer circle indicates the distribution of underground water in the five prefecture-level cities while the inner circle indicates the distribution of surface water.
Source: 2012 Ningxia Water Resources Communiqué
It is worth noting that climate change may aggravate Ningxia’s water stress. Studies show that global warming will cause the water resources of the Yellow River Basin to decline, which will add to the water risk of those regions relying heavily on the River.

The Status Quo: Water Consumption in Ningxia

The main water demand in Ningxia comes from agriculture, industry, and from rural and urban households. In 2012, Ningxia’s total water withdrawal was 6.933 billion cubic meters, including 0.543 billion cubic meters of underground water. Of this 6.246 billion cubic meters (90.1%) was for agricultural use; 0.487 billion cubic meters (7.0%) for industrial use; 0.063 billion cubic meters (0.9%) for rural household use and 0.137 billion cubic meters (2.0%) for urban domestic water use (see Figure 4).

Industrial Water Use

Industrial growth picked up speed from the start of the 10th Five-Year Plan, marked by the development of the Ningdong Base. At the end of the 10th FYP, Ningxia’s electricity generation had grown 109.4% and the coal production had expanded 64.4% from 2000. In the 11th FYP, Ningxia invested in a number of major projects in coal, electric power and coal to chemicals sectors. The Ningdong Energy and Chemical Industry Base (referred to as “Ningdong Base” below) is now a national-level development zone. Supporting industries grew rapidly as did their appetite for water. In the 12th FYP, Ningxia continued to construct Ningdong Base, a thermal power project to transmit power from the west to the east and a coal-chemical base. Industrial added value jumped 36.6% from 2010 to 2012. Meanwhile, in the same period, Ningxia’s industrial water withdrawal increased by 18.2%, and industrial water consumption increased by 48.2% (see Figure 5).

By the end of the 12th FYP, Ningxia’s water withdrawal reached 7.3 billion cubic meters. By the end of 2012, in the second year of the plan, Ningxia had already used up 95% of the water it planned to use although it had only completed 72% of its goal (see Figure 6). This aggravated competition over water access.
2. Agricultural Water Use

Agriculture makes up about 10% of Ningxia’s annual GDP but it consumes much more water resources\(^4\). In 2012, Ningxia’s 19.07 million Mu of arable land\(^4\) withdrew 6.246 billion cubic meters, or 90.1% of the total water withdrawn that year, which is much higher than the national average is 63.6\(^{42}\).

The water use efficiency of the agricultural sector is significantly low. In 2012, the agricultural irrigation water use coefficient was 0.45\(^43\), which is much lower than the national average of 0.516\(^44\). It has a long way to go before “hitting the 0.48 goal by 2015” wrote in the Ningxia’s Strictest Water Resources Management Schemes\(^45\).

Water shortages and inefficient water use are two factors hindering the development of the agricultural sector and other economic activities. Hence, the region has been researching more efficient irrigation methods. Advanced techniques have already been introduced to 450,000 Mu of land in Ningxia in 2013; so far 1.65 million Mu of land or 20% of the region has been irrigated in this way. This pilot program has been approved by the Ministry of Water Resources and has been integrated into a program to improve the efficiency of irrigation in northwestern China\(^46\).

3. Domestic Water Use

Figure 6 | Ningxia’s Coal Production and Total Water Consumption (2012, 2015)

There is a huge discrepancy between population distribution and water resources distribution (see Figure 7). In 2012, Yinchuan had 31.6% of Ningxia’s population but used just 18.9% of its water (excluding water drawn from the Yellow River); Wuzhong had 20.3% of the population but used 12.3% of its water (excluding water drawn from the Yellow River).

In 2012, Ningxia’s GDP per capita was 36,394 yuan (at current prices) while daily water consumption per capita was 156.5 liters, ranked about middle in the nation (see Figure 8). It is worth noting that Tianjin, another region suffering from water shortages has a GDP per capita 2.5 times that of Ningxia. Tianjin’s daily water consumption per capita is 85.8% of Ningxia’s, which suggests that Ningxia can do a lot to improve the efficiency of domestic water usage.

**Figure 7 | Comparison of the Population and Water Resources of Ningxia’s Prefecture-level Cities (2012)**

Source: Ningxia Statistical Yearbook (2012)

**Figure 8 | Comparison of Economic Development and Domestic Water Usage of 31 Provinces, Autonomous Regions and Municipalities (2012)**

COAL INDUSTRY DEVELOPMENT AND WATER STRESS IN NINGXIA

The coal industry has brought Ningxia both economic benefit as well as exacerbated water stress. In 2012, the Ningdong Base consumed 97 million cubic meters of water, which is 20.0% of the total volume consumed by industry in the region that year. It is estimated that in 2015 the base will consume 194 million cubic meters and 641 million cubic meters in 2020. The energy industry, as the region’s pillar industry, is expected to grow 12.6% per year during the 12th FYP period. The region accounted for the increase in air pollution, but it did not consider the extra pressure on water that this growth would incur.

The Status Quo: Up and Down Stream of Ningxia’s Coal Industry

The secondary and tertiary sectors are the main drivers of Ningxia’s economic growth in 2012, the secondary sector contributed 38.0% to GDP growth while the tertiary sector contributed 42.0%. Of the contribution from industry, the energy sector contributed 50.0% of the growth, indicating that energy is already Ningxia’s pillar industry.

1. Coal Production

Ningxia has abundant coal reserves, including high quality coal and various types. Coal is relatively easy to mine in this region. So far, Ningxia has had 3.15 billion tons of proven reserves, and another 202.7 billion tons of coal is suspected, which would make it the region or province with the 6th biggest coal reserves in China. Industrial development has driven up coal consumption. In 2012, Ningxia consumed 80.55 million tons of coal, 7.7 times greater than 2000. According to its 12th FYP, coal production capacity is expected to pass 100 million tons.

In 2012 there were only 3.234 billion tons of its proven coal.

Figure 9 | Coal Industry Development of Ningxia (2003-2012)

Note: Drawn by China Water Risk and WRI Source: website of National Bureau of Statistics
reserves left, 47.3% of the figure in 2003\(^5\) (see Figure 9).

Ningdong has 27.3 billion tons in coal reserves, accounting for 87.0% of the Ningxia’s total. This makes Ningdong one of the 14 key development coal mining regions with the capacity of over 100 million tons\(^5\). Ningdong will be developed into one of the country’s key coal bases (see Box 2).

### 2. Coal Consumption

#### Thermal Power Generation

Ningxia has focused on growing its power generation sector in recent years to meet demand from economic growth, industrialization and urbanization. In 2012, total installed capacity for electricity generation was 16.40 million kilowatts, 8 times of that in 2000\(^7\). According to Ningxia Hui Autonomous Region 12th Five-Year Plan for Energy Development, capacity is expected to reach 30 million kilowatts in 2015, that is an increase of 82.9% from 2012 (see Figure 10)\(^8\). Despite recent efforts by the government to restructure its energy mix and to increase the share of renewable energy, thermal power is still the dominant means of power generation, with a share of over 80%.

It is worth noting that a large share of Ningxia’s electricity is transmitted outside the region. In 2011, Ningxia transmitted 26.0 billion kWh outside the region, which is 26.0% of the total electricity output\(^9\). It is projected that in 2015, that proportion could jump to 32.1%\(^10\).

#### Coal-Based Chemical Industry

Ningxia’s abundant coal reserves have prompted a lot of interest in developing Ningxia as a major base for a coal-to-chemicals industry. Before 2008, the main coal-to-chemicals were fertilizer, PVC, calcium carbide...
and coke⁶¹. Ningxia published its *Ningxia Coal-Based Chemical Industrial Cluster Development Plan (2008 – 2012)* in 2008, indicating that it regarded this sector as an important one for its future economic growth. It earmarked products such as methanol, PVC, dimethyl ether, synthesis ammonia, olefin and indirect coal liquefaction as key areas. It earmarked four industrial clusters: Ningdong Base, Wuzhong Taiyangshan Coal-based Chemical Industrial Base, Shizuishan Coal Chemical Industrial Base and Zhongwei Coal-based Chemical Industrial Base. Each base would have its own focus.

The Outline of Ningxia Hui Autonomous Region’s 12th FYP for Economic and Social Development, offered further details on advancing coal-based olefins, coal oil and coal gas production schemes. By 2015, the production of the coal-based chemical industry could reach over 10 million tons. The outline suggested that new technology would be imported to drive the sector and make it the biggest contributor to GDP in the region. However, the coal-to-chemicals industry is very water intensive.

**Ningxia’s Coal Industry Development and Water Stress**

Water demand by the coal industry – both upstream and downstream – in Ningxia is very high. At the end of 2012, Ningxia had more than 90 power plants and each of them with an annual power generation of more than 6,000 kilowatts, among which 82.8% were coal power stations, 11.2% were wind power stations and 6% came from other sources (including photovoltaic power, hydropower, solar power and waste incineration power). Figure 11 shows BWS and the distribution of power plants of the prefecture-level cities in Ningxia. Dots of different colors indicate different types of power plants; the diameters of the dots suggest the relative sizes of each plant; colors from yellow to red indicate different levels of water stress. The darker the color, the more water stress the region experiences. 91.5% of the power plants are located in areas suffering from serious water shortages.

The *Ningxia Energy Development Plan* and the Ningdong Base asked each of its plants to install air cooling units. According to WRI’s analysis, however, air cooling units only account for 62.8% of the total installed capacity of Ningxia’s thermal power plants. But if we only look at the Ningdong Base, by 2015 its thermal plants are expected to be 1.9 times larger than 2010 levels (6000 megawatts) and 2.9 times larger by 2020, and the water consumption will rise 1.5 times by 2015 and 2 times by 2020. Thus, higher water risk will be associated with the scale up of thermal power plants⁶².

The 12th FYP also mentions that development of the coal-to-chemicals industry will significantly drive up water demand. It estimated that by 2015, the coal-to-chemicals industry would consume 13.045 million cubic meters of water (3.1 times of that in 2011), and 17.659 million cubic meters in 2020 (4.3 times of that in 2011)⁶³. Figure 12 shows the variation trends for the Ningdong Base’s water demand and supply. The Base will need to draw water from the Yellow River or recycle water.

It is worth noting that there is a dearth of data on the water consumption of the coal mining and coal-to-chemicals sector in Ningxia. Since they are both very water intensive, more effort is needed to collect data on these two sectors in the future.

**Water Management in Ningxia’s Coal Industry Development**

Aware of the danger of unsustainable water consumption of the coal-fired power sector, the Ministry of Water Resources published *Opinions on Carrying out Effective*...
Water Resource Argumentation for the Planning of Large-Scale Coal Power Bases (referred to as “Opinions” below) in December 2013, urging all large-scale coal-fired power plants to adopt the strictest measures possible to reduce water consumption. It also suggested that constraints on the use of water resources should be done at the same as the planning for the coal bases. The document suggested that those regions that have reached or exceeded limits set on water consumption could follow the plan set out by the provincial level Water Resources Department and improve the efficiency of water use and water right transfer.

Taking Ningdong Base as an example, it finished its water resources planning argumentation report in September 2012, and the Ministry of Water Resources approved the report in January 2014. This report estimated that the base could extract 39.0% of its water needs from the Yellow River in 2015 and 84.0% of its water needs from the River by 2020.

Ningdong Base has also published several plans on water usage and a series of administrative and economic measures have been adopted to encourage companies to save water, reduce water consumption and reuse wastewater with the eventual goal of having “zero emission” of wastewater. In 2014, Ningdong Base set up a strict environmental protection plan which included assessments of energy efficiency, zero-emission programs, and wastewater recycling etc. The general aim was to reduce emissions discharged into the Yellow River. The Base is the first in the country to have such a large environmental protection scheme in place.
WATER RESOURCES MANAGEMENT OF NINGXIA

The local government has drawn up a number of policies and economic measures to improve efficiency and ensure sustainable use of water resources. This chapter discusses the most important measures—water saving, water right transfer and water pricing.

Water Resources Management Framework and Main Duties

The Water Resources Department, the Environmental Protection Department and the Housing and Urban-Rural Development Department of Ningxia respectively manage Ningxia’s water resources, water environment and water supply and drainage. Water resources management is handled top-down from the central ministries (including the Yellow River Conservancy Committee (referred to as “YRCC” below) of the Ministry of Water Resources) to the Ningxia regional government to prefecture-level cities and finally to counties, altogether four levels. All administrative departments conduct their work within the scope of their duties under the guidance of the governments at the same level. Figure 13 shows the details of the water resources management framework.

The Water Resources Department is responsible for managing water use in the whole region. This includes making plans and standards regarding water resources development and exploitation, managing water resources, ensuring the domestic, production and ecological water use, water saving, control flooding, protecting soil and water quality inspections. The Environmental Protection Department is responsible for protecting water environments, conducting environmental impact assessments for construction projects, monitoring emissions permits and enforcing environmental laws. The Housing and Urban-Rural Development Department looks after municipal water supply, wastewater treatment and utilization.

Figure 13 | Water Management Framework of Ningxia
The YRCC also overlooks the utilization of water from the Yellow River in Ningxia, under the administration of the Ministry of Water Resources. This includes the allocation and scheduling of water use, enforcing quotas, issuing drainage permits and resolving conflicts over access to water resources between different provinces and regions. Water-Saving Management

The barriers to Ningxia’s socio-economic growth are the region’s scarcity of water resources and the inefficiency of their use. It is becoming more urgent to solve these problems faced with rapid growths in urbanization, industrialization and population. The local government has issued two policy directives, one in 2004 called Planning Outline of Ningxia’s Water-Saving Society Construction (2004-2020) and the other in 2007 called Water Conservation Regulations of Ningxia Hui Autonomous Region (Revision of 2012) to help improve water-saving management. These two documents require water authorities at or above the county level to issue plans for saving water, to set quotas for industry on water use, issue water intake permits, apply extra costs for exceeding quotas and encourage the uptake of new technologies.

Ningxia also requires enterprises to put in place a system to reuse water. Efforts to save water were first announced in 2004, and progress has been made. Water consumption per 10,000 yuan of GDP fell from 1,274 cubic meters to 298 cubic meters (a fall of 76.6%) between 2004 and 2015. Water consumption per 10,000 yuan of industrial added value dropped from 173 cubic meters to 55 cubic meters (a fall of 68.2%). This improvement in efficiency has significantly relieved the pressure on water resources, especially given the rapid expansion of the coal industry. Between 2000 and 2012, industrial water withdrawal rose 12.7% to 487.3 million cubic meters while industrial added value rose six times over the same period, reaching 86.06 billion yuan.

Water Right Transfers

Water right transfer means that if an industrial enterprise invests in agricultural water-saving projects in specific districts designated by the YRCC it will be awarded credits for industrial water use. This method will relieve the pressure on industrial water and assist in the growth of an intensive and large-scale agricultural sector. As mentioned earlier, there is significant potential for saving water. It is not possible to increase Ningxia’s water resources and so the region is using water right transfers to improve water use structure and allocation efficiency of water resources to resolve industrial water use problems.

Currently water right transferred in Ningxia is obtained through retrofitting the main canal to reduce water losses. The Water Resources Department of Ningxia signs water transfer contract with industrial enterprises representing Ningxia Government and has the power to monitor industrial enterprises’ water right transfers. The price of water transfers can vary depending on the project period and total cost. The transfer price will rise along with the increase in the main canal retrofit and the decrease in the potential for saving water falls. By June 2013, there had been nine water right transfers projects (88 million cubic meters) in Ningxia.

This system can help industry solve issues related to water use and also drives more efficient water use for economic development. It also restricts companies using fresh water. The system has encouraged improvements in water saving technologies. Over the last 10 years, Shuidonggou and Yuanyanghu power plants have annually saved more than 70 million cubic meters of water through water right transfers.

Ningxia has set up the water right transfer platform between the government and enterprises. We suggest that Ningxia conduct studies on setting up similar systems for the transfer of water rights between farmers and
enterprises, and between different enterprises, as well as policies and techniques that have saved water in the canal and providing the money needed to achieve this.

**Water Price Reform**

1. **Water Resources Fees**

Ningxia did not start charging for water use until much later than the rest of the country and even the costs charged are low compared to other areas. In 2012, surface water costs in the cities was 1/3 of the cost in Gansu; 1/4 of the cost in Shaanxi and 1/7 of the cost in Shanxi, all areas are suffering from a scarcity of water resources and ones where the energy industry is undergoing rapid growth. The cost for underground water in Ningxia is 2/3 of the cost in Gansu; 1/3 the cost in Shaanxi, and 1/10 of the cost in Shanxi. Some companies extract surface water themselves and they should also be charged properly for this, yet fees in Ningxia are just 1/2 of those charged in Gansu, 1/4 of those in Shaanxi and 1/10 of those in Shanxi.

These low costs are not in line with the scarcity of water resources in the region and so at the end of 2013, Ningxia adjusted the water resources fees, which took effect on January 1, 2014. Table 1 shows the water resources fees standards of different water uses in Ningxia. Although the costs for surface water rose to 0.17 yuan per cubic meter while the fee for underground water increased to 0.41 yuan per cubic meter, they are still far below the national average which is 0.30 yuan per cubic meter for surface water and 0.70 yuan per cubic meter for groundwater. It is expected that Ningxia will increase the fee of surface water to 0.297 yuan per cubic meter for surface water and 0.717 yuan per cubic meter for groundwater by 2016.

2. **Water Prices**

   - **Agricultural Water Prices**

Ningxia’s agricultural water prices are comparatively lower than that of other uses. In 2008, Ningxia raised

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**Table 1 | Water Resources Fees Standards in Ningxia**

<table>
<thead>
<tr>
<th>Industry</th>
<th>Unit</th>
<th>Surface Water (including reservoir and lake water)</th>
<th>Underground Water (including geothermal and mineral water)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>City Water</td>
<td>Ex-City Water</td>
</tr>
<tr>
<td>City public water supply</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Domestic water use</td>
<td>m³</td>
<td>0.15</td>
<td>0.20</td>
</tr>
<tr>
<td>Industrial and commercial water use</td>
<td>m³</td>
<td>0.15</td>
<td>0.30</td>
</tr>
<tr>
<td>Water use for special industries</td>
<td>m³</td>
<td>1.00</td>
<td>2.00</td>
</tr>
<tr>
<td>Self-providing water</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Domestic water use</td>
<td>m³</td>
<td>0.20</td>
<td></td>
</tr>
<tr>
<td>Industrial and commercial water use</td>
<td>m³</td>
<td>0.20</td>
<td></td>
</tr>
<tr>
<td>Water use for special industries</td>
<td>m³</td>
<td>1.50</td>
<td></td>
</tr>
<tr>
<td>Hydroelectric water use</td>
<td>kWh</td>
<td>0.003</td>
<td></td>
</tr>
<tr>
<td>Coal mining water withdrawal and drainage</td>
<td>m³</td>
<td>Fees are calculated based on the amount of water used and there is also a charge for water drainage, Which is 0.2 yuan/m³. This cost would be waived if water is recycled.</td>
<td></td>
</tr>
<tr>
<td>Oil exploitation water use</td>
<td>m³</td>
<td>Fees are calculated based on the total amount of water used and self-owned, underground, industrial and commercial standard. If the company has a meter, the fee should be based on self-owned, underground, industrial and commercial standard. If it does not have a meter then the fee should be based on one meter depth, one cubic meter consumption.</td>
<td></td>
</tr>
<tr>
<td>Commercial water landscape and water for tourism</td>
<td>m³</td>
<td>The fee for surface water is 0.01 yuan/m³. The fee for groundwater depends on the industry.</td>
<td></td>
</tr>
<tr>
<td>Water use for ground source heat pump</td>
<td>m³</td>
<td>The fee for recharging is 0.10 yuan/m³. The rest is based on self-owned water source ground water classification standard.</td>
<td></td>
</tr>
<tr>
<td>Precipitation and drainage for city construction</td>
<td>m³</td>
<td>Based on the total quantity of water actually drained at the price of 0.50 yuan/m³.</td>
<td></td>
</tr>
</tbody>
</table>

Note: These fees were brought in on January 1, 2014
supply water prices of water conservancy projects in the Yellow River irrigation districts. It charged farmers (crops, forest and grassland) 0.0305 yuan per cubic meter (The main canal water price is 0.0250 yuan per cubic meter and the price for lateral canals is 0.0055 yuan per cubic meter). This is much lower than the national average of 0.0900 yuan per cubic meter. Low prices are thought to be the main reason why Ningxia’s agricultural water use is so inefficient.

Industrial and Domestic Water Prices

In 2014, industrial water prices in Ningxia (including sewage treatment fee) was 3.75 yuan per cubic meter, ranking 13th among the 31 provincial capitals in the country. Domestic water price (including sewage treatment fee) in Ningxia was 2.50 yuan per cubic meter, ranking 20th. (See Figure 14 and Figure 15)84.

Therefore we can see that water prices in Ningxia are set too low when viewed against the scarcity of water resources in the region and the natural, economic, social and environmental factors that affect the value of water resources. Low water prices do not encourage water saving or efforts to improve water use efficiency.

Ecological Compensation

Ningxia’s environment is fragile due to historical and geographical reasons. Ningxia regional government has brought in a number of ecological compensation measures for forest, grassland and mine resources. Mining companies were forced to pay a compensation fee in 199485 and measures were brought in on how to settle compensation in 2002 by the regional government86. The regional government also launched a project in 2010 connected with protecting the mining environment87, investing 116.7 million yuan into this in 2010, which is the highest in history and the sum of the investment over the years.

Although Ningxia has made efforts in the ecological compensation of mine resources, there are many problems. The current compensation fee of mine resources cannot pay for all the damages to the environment that has been caused by mining. This financial tool that is aimed at protecting the environment is immature and lacks a payment mechanism between central and local governments and a transfer payment mechanism between different provinces. Policies are incomplete – for example they do not even define the responsibilities for the parties involved.

In addition to the ecological compensation of mine resources, Ningxia still lacks the ecological compensation of basin water environment. Ningxia has started working on water conservation but so far only the lower reaches of the Yellow River have benefitted. The government should also establish a cross-regional ecological compensation system to force other provinces to pay Ningxia ecological compensation.

CONCLUSIONS AND SUGGESTIONS

1. High baseline water stress, unsustainable development of water resources and limits to energy industry growth from limited water resources

According to the WRI’s Aqueduct water risk framework, more than 70% of Ningxia faces very high levels of baseline water stress. In 2012, water sustainability of Ningxia was 8.2, which means unsustainable water use. The two cities in Ningxia with the highest water use intensity and water stress are Yinchuan and Shizuishan. Both cities have very limited water resources but most of Ningxia’s economic outputs and populations.

WRI’s Aqueduct baseline water stress map also shows that 91.5% of installed capacity of from coal-fueled power plants is located in areas suffering from severe water shortages. It is likely that Ningxia’s energy industry will face many obstacles in achieving sustainable development and industrial transformation.

2. Ningxia should prioritize water conservation, in particular improve the efficiency of agricultural water use

About 90% of total water withdrawn in Ningxia is used for agricultural purposes. This proportion is much higher than other big agricultural provinces (such as Liaoning, Shandong and Fujian Province). Ningxia’s agricultural water use is comparatively inefficient. Its agricultural irrigation water use coefficient in 2012 is 0.45, which is lower than the national average level and is much lower
Figure 14 | Domestic Water Prices for China’s 31 Provincial Capitals (2014)

Note: There is no information on sewage treatment fees for Lhasa.
Source: www.h2o-china.com

Figure 15 | Industrial Water Prices for China’s 31 Provincial Capitals (2014)

Note: There is no information on sewage treatment fees for Lhasa.
Source: www.h2o-china.com
than its 2015 target (0.48) and 2020 target (0.53). In terms of its water conservation work, Ningxia should prioritize encouraging the building of water-saving projects, finding new sources to fund agricultural water-saving projects, adjusting cropping structure and so on. To achieve this they have used a variety of measures such as government support, market guidance and farmer participation.

Ningxia must also target the efficiencies of industrial and domestic water use and encourage the adoption of water-efficient equipment and technologies.

3. Ningxia should incorporate water resources into the energy/coal industry development plan as a restrictive factor; promote sustainable development of the energy/coal industry and the sustainable exploitation and utilization of water resources

The rapid growth in both the upstream and downstream sectors of the water-intensive coal industry in Ningxia is posing a huge challenge to the region’s water resources, and water shortage also prevents the sustainable development of the industry. The existing policy framework treats water and energy as separate elements in Ningxia. The local government’s 12th FYP does not even include water resources as a key factor in the energy sector’s sustainable development. The region’s water resources plan does mention the effect of energy industry growth, but there is a huge discrepancy between this plan’s estimation and the goal set out in the energy plan.

It is essential that energy and water management agencies collaborate more closely to ensure the sustainable development of water resources and energy. Decision makers should treat water as a restrictive factor while drawing up development plans for the energy/coal industry and promote the sustainable development of the industry as well as sustainable exploitation and utilization of water resources.

4. Ningxia should study water rights transfer and promote a water right trading mechanism

The piloting was started in 2003 and till June 2013, 88 million cubic meters of water was transferred from agriculture to the industrial sector. This is an effective way to meet the industrial sector’s demand for water as well as help to provide funds for reconstructing agricultural water-saving irrigation.

The 18th CPC National Congress put forward to enhance water right transfers and explore water rights trading. In July 2014, the Ministry of Water Resources ordered Ningxia and other six provinces to give the agricultural sector a cap for water withdrawal from the Yellow River, surface water and groundwater resources. Water right allocation should be accompanied with various forms of entitlement registrations. The Decision to Deepen Reform and Propel the Development of Economy and Society of the Ningxia Hui Autonomous Region outlined a plan to set up a market to trade water rights on the premise of not impacting agricultural water use.

Since a transfer platform between companies and the government has already been set up in Ningxia, the next step is to study water rights trading between corporations and farmers and within corporations. Therefore, Ningxia should invest into research and mechanism design that would establish the best water rights trading mechanism, policies and management system to support water saving in irrigation and trading between corporations.

5. Ningxia should accelerate the reform of water prices, raise water resource fees, and exploit price leverage to encourage water saving

Water resources fees are a key tool in encouraging water saving practices and making sure water resources are used sustainably. In 2014 industry paid 3.75 yuan per cubic meter for water (including sewage treatment fee) in Yinchuan. This figure is ranked 13th among the 31 provincial capitals of China. Households paid 2.5 yuan per cubic meter (including sewage treatment fee) in Ningxia, ranking 20th among the 31 provincial capitals of China. If we compare this with the average per capita income in Ningxia, a normal family would spend just 0.5% of their disposable income per capita on water. In 2014, both surface water and underground water fees were only 59.0% of the government’s target set in the 12th FYP. Ningxia’s current water rates and water resource fees have been set too low to reflect the real value of water scarcity in terms of water resources. This means that the
government is not exploiting price leveraging to encourage better water conservation among the various sectors. Ningxia should raise water resource fees to encourage the industrial sector to conserve more water and accelerate the collection of mining drainage fee so that coal companies are encouraged to reuse mining drainage water and use less fresh water.

The local government should also impose a drainage water fee on coal mining companies to encourage the reuse of drainage water. Shanxi province charges mining companies 1.2 yuan per cubic meter of drainage water used. For Companies that do not have equipment to measure the amount of drainage water removed, the fee is 3.0 yuan per ton of coal. However, in Ningxia the fee for drainage that took effect on January 1, 2014 is only 0.2 yuan per cubic meter, clearly much lower than that of Shanxi Province.

The government’s fee collection system is not well developed. Many companies in Ningxia do not have water meters and procedures are not properly followed when fees are collected. The monitoring of water consumption and the collection of water resource fees can be improved by installing more and better measuring equipment.

6. Ningxia should set up the eco-compensation mechanism for the mining sector and start the pilot program on eco-compensation within and across river basins

The government has championed eco-compensation systems since 2005. In the 12th FYP, the central government said it would set up reserve funds for the sustainable development of resource-based enterprises. The 18th CPC National Congress called for local governments to set up paid use systems and ecological compensation systems reflecting market supply and demand, resource scarcity, ecological values and the trans-generational compensation. Ningxia has already begun work on ecological compensation of mine resources. In 2010, Ningxia invested 116.70 million yuan to manage its mines, the biggest amount yet for the region. These funds have provided essential fund for the ecological compensation system for mine resources. However, Ningxia does not currently have an eco-compensation mechanism for the mineral mining sector. Compensation fund sources and compensation solutions are not diversified, while the delayed management of old mining sites has blocked progress on this work.

Efforts to promote environmental protection within the management of mines so far has only included transfer payment from the central government to local governments and mining companies must pay environmental restoration deposits. Ningxia should study how various economic tools can be used to force companies to use the fund exclusively for eco-compensation, to protect the environment and water resources in mining areas and manage pollutants and so on.

The environmental restoration deposit is only imposed on new mining companies and new environmental damages caused by mine development. However, previous environmental destruction in old mining and industrial areas has caused far more extensive damage such as Shizuishan industrial zone. Ningxia should also focus on cleaning up and reforming these companies.

It should also launch pilot projects on eco-compensation to promote the environmental protection of the river basin water. As part of this project, provinces downstream should compensate for Ningxia’s efforts on improving water conservation and water quality.
APPENDIX: WORLD RESOURCES INSTITUTE (WRI) AQUEDUCT BASELINE WATER STRESS INTRODUCTION

Methodology

WRI’s Aqueduct Water Risk Framework uses baseline water stress to assess the water risk of an area. When the ratio is higher than 0.4, the water risk is high. When the ratio is higher than 0.8, the water risk is extremely high. The higher the baseline water stress, the greater the competition for water, and thus the higher the risk.

In order to analyze the baseline water stress of Ningxia, we measure the basic indicators including volume of run off, water consumption, total amount of water resources and available water amount.

1. Baseline Water Stress

Baseline water stress is the ratio of total water withdrawal to available water amount, and the computational formula is:

\[
\text{Baseline Water Stress} = \frac{\text{Total Water Withdrawal}}{\text{Available Water Amount}} = \frac{(\text{Agricultural Water Withdrawal} + \text{Industrial Water Withdrawal} + \text{Domestic Water Withdrawal} + \text{Other Water Withdrawal})}{(\text{Volume Of Run Off} - \text{Water Consumption Of Upstream})}
\]

2. Measure of Runoff Volume

We computed annual runoff for Ningxia Region and each of its prefecture-level cities using the Global Land Data Assimilation System Version 2.0 (GLDAS-2). One degree data were available from 1948-2010 while the 0.25° data were available from 1948-1999. GLDAS-2 uses NOAH v.3.3 to generate surface and subsurface runoff. The surface and sub-surface runoff was re-sampled to 30 arc-seconds and then converted to volume by multiplying by the area of each pixel. Furthermore, we used Global Administrative Areas (GADM) dataset (v.2.0) for the province and district boundaries.

Appendix Figure 1 shows the GLDAS-2 simulation situations of Ningxia surface run off. The darker the color, the less the surface run off volume. For example, Shizuishan City, located in the northern Ningxia, is the prefecture-level city with the least surface run off volume in Ningxia. Its surface run off volume was only 11.9% of that of the region in 2012. It is worth noting that the 0.25° data can better simulate the spatial runoff distribution due to higher accuracy.

3. Spatial Analysis of Water Consumption

The Ningxia government provided water withdrawals and consumptive use for 2011 for each of the five districts. The Yellow River Conservancy Commission provided water use by sector (e.g., agricultural, industrial, and domestic sectors) for the other provinces within the Yellow River Basin. Agricultural withdrawal included forestry, husbandry, and fishery withdrawals. For each water use sector, the surface and groundwater components were combined.

Appendix Figure 1 | Map of Ningxia and Runoff Coverage of GLDAS-2 1° and 0.25°
Water use by sector was disaggregated using spatial correlates:

- For agricultural water withdrawals, we computed Area Actually Irrigated in 2005 as Area Equipped for Irrigation × Percent of Area Equipped that was Irrigated from the Global Map of Irrigation Area (GMIA) v.5 (Siebert et al. 2013). Agricultural withdrawals and consumptive use were distributed proportionally to .

- Industrial and domestic withdrawals and consumptive use were spatially disaggregated using 1 kilometer grids representing water use for these two sectors in China in 2000 from Chinese Academy of Sciences. This dataset was used because they demonstrated the highest correlation between 2011 reported withdrawals and the sum of the spatial grids in the provinces within the Yellow River Basin and districts in Ningxia.

4. Total Blue Water and Available Blue Water

Runoff was routed by catchment using the Aqueduct Flow Accumulation Framework.

Total blue water was computed as the accumulated sum of runoff in each catchment to the downstream catchment. Available blue water was handled similarly but with consumptive use removed before passing water to the downstream catchment. In addition, prior to the calculation of transfers were incorporated. The volume of the starting point of the transfer was added to the total and consumptive use component of the originating catchment and the volume of water was added to the runoff of the receiving catchment.

5. Calculation Results Validation

Two different data sources for runoff were compared to each other. These included runoff reported by the Ningxia government and runoff calculated by NASA from satellite imagery.

At a province level, there was good agreement between GLDAS-2 data with the reported runoff (annual surface water resources). The 1° GLDAS-2 data averaged slightly higher than both the 0.25° GLDAS-2 and the official record. There was an exception and a possible outlier in 2002 where the 1° was much higher than the official record.

As noted, 0.25° GLDAS-2 allows for better spatial distribution runoff and therefore more spatial variability than 1° GLDAS. (See Appendix Figure 2 and Appendix Table 1).

At the city level, 1° runoff was consistently higher than the 0.25° runoff except in Yinchuan City. Yinchuan’s official record was higher than the 1° runoff in three out of the five prefecture-level cities (See Appendix Figure 3). Due to the difference in spatial variability of runoff, comparing runoff with the official record gets more accurate at a province level as compared to a city level.

No alternative source of water withdrawal data exists to validate the withdrawals.

Data Source

The World Resources Institute’s Aqueduct Water Risk Atlas used publicly available global datasets. Ningxia’s water stress map used datasets provided by the Ningxia government (see Appendix Table 2).

<table>
<thead>
<tr>
<th>Runoff Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1° GLDAS - 0.25° GLDAS</td>
</tr>
<tr>
<td>1° GLDAS – Ningxia’s runoff</td>
</tr>
<tr>
<td>0.25° GLDAS – Ningxia’s runoff</td>
</tr>
</tbody>
</table>

Source: WRI Aqueduct
Appendix Figure 2 | Comparison of Runoff from 0.25° and 1° GLDAS-2 with Ningxia Official Record

(a) Comparison of Runoff Results of Different Data Sources (1948-2012)

(b) Comparison of Simulation Runoff Results of Different Data Sources (1990-2010)

(b) Comparison of Simulation Runoff Results of Different Data Sources (1990-2010) (Excluding the outlier)

Appendix Table 2 | Summary of Datasets for Aqueduct’s Global, River Basin, and Provincial Level Maps

<table>
<thead>
<tr>
<th>Data</th>
<th>Source</th>
<th>Year</th>
<th>Resolution</th>
<th>Website Link</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aqueduct’s Water Risk Atlas</td>
<td><img src="image" alt="Aqueduct’s Water Risk Atlas" /></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water consumption</td>
<td>World Water Resources at the Beginning of the Twenty-First Century</td>
<td>2010</td>
<td>Region</td>
<td>-</td>
</tr>
</tbody>
</table>

Ningxia’s Baseline Water Stress Map

<table>
<thead>
<tr>
<th>Data</th>
<th>Source</th>
<th>Year</th>
<th>Resolution</th>
<th>Website Link</th>
</tr>
</thead>
</table>
Applicability of Aqueduct’s Global Model for Ningxia

There are several challenges and opportunities of applying a global model to a province. Appendix Figure 4 compares the Yellow River basin water stress map using different data sources (i.e. Aqueduct global data and Ningxia official data).

Results from the Aqueduct’s Water Risk Atlas and Ningxia’s water stress map are compared and discussed. However, it is important to note that there are differences between the methodology and data. The maps were generated with different datasets. Furthermore, transfers were included in Ningxia’s water stress map but not Aqueduct’s Water Risk Atlas. Appendix Table 3 compares the methodology and the data of the two maps.
## Methodology and Data Differences between Aqueduct’s Water Risk Atlas and Ningxia’s Water Stress Map

<table>
<thead>
<tr>
<th>Map</th>
<th>Methodology</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aqueduct’s Water Risk Atlas</td>
<td>Spatial disaggregation: Uses industrial night lights and population density for industrial and domestic water use. Available blue water, does not include inter-basin transfers.</td>
<td>Used 2010 water withdrawal data</td>
</tr>
<tr>
<td>Ningxia’s Water Stress Map</td>
<td>Spatial disaggregation: Uses 1 km grids representing water use in from Chinese Academy of Sciences for industrial and domestic water use. Available blue water. Includes inter-basin transfers.</td>
<td>Used 2011 water withdrawal data</td>
</tr>
</tbody>
</table>
ENDNOTES

1 Data from Water Resources in Ningxia, Water Resources Department of Ningxia.

2 Data from Ningxia Water Resources Bulletin (2013), Water Resources Department of Ningxia.


4 Data from Ningxia Water Resources Bulletin (2012), Water Resources Department of Ningxia.


6 In accordance with internationally accepted standards, the water resources per capita of less than 3000 cubic meters falls into the category of mild water shortage; the water resources per capita of less than 2000 cubic meters is moderate water shortage; the water resources per capita of less than 1000 cubic meters is severe water shortage. Source: http://amuseum.cdstm.cn/AMuseum/diqiuziyuan/wr0_4.html

7 Yellow River irrigation areas in Ningxia Region: the Yellow River irrigation areas of Qingtongxia City, Yongning County, Yinchuan City, Helan County, Pingluo County, Huining District, Shizuishan City, Zhongwei City, Zhongning City, Wuzhong City and Lingwu City and over 20 state-owned farms, forestry and pasture.

8 Data from Ningxia Water Resources Bulletin (2012), Water Resources Department of Ningxia.

9 Irrigation water utilization coefficient is ratio between the net water utilized by the crop and the total irrigation water volume during one irrigation period. It is an important indicator to measure the utilizing efficiency of irrigation water when diverting water from the source to the field.


11 According to The Outline of the National Ecologically-Fragile Zones Protection Plan, ecologically-fragile zones refer to the transition area of two different types of ecosystems. These zones are weak with interference, sensitive to global climate change and easy to experience spatial and temporal fluctuation. They also have strong edge effects and environmental heterogeneity.


13 http://nx.cnr.cn/xwzx/xw/201201/t20120111_50904227.shtml

14 According to The Twelfth Five-Year Plan for Ningxia’s Energy Development, the consumption of new energy resource and natural gas accounts for 2.5% and 4.5% respectively of the total energy consumption, with coal accounting for 85%.

15 http://www.nxnews.net/sz/system/2014/05/13/011018987.shtml

16 Data from The Statistical Bulletin of the National Economic and Social Development of the Ningxia Hui Autonomous Region in 2012, Statistical Bureau of Ningxia.

17 According to The Statistical Communique of the People's Republic of China on the National Economic and Social Development over the years, it is assessed that Ningxia’s energy use per 10000 yuan of GDP in 2012 is 3.280 ton of standard coal, 3.4 times of the national average level over the same period.

18 Data from The Twelfth Five-Year Plan for Ningxia’s Energy Development. Ningxia Hui Autonomous Region Government.

19 Baseline water stress is used to measure the competition level and the sustainability of a region’s water utilization. It is the ratio between the total water assumption of a region and its available water volume.

20 Data from Ningxia Comprehensive Water Resources Plan, Water Resources Department of Ningxia.

21 Data from The Basic Condition of Ningxia’s Water Resources, Water Resources Department of Ningxia.

22 Data from The Basic Condition of Ningxia’s Water Resources, Water Resources Department of Ningxia.

23 Data from The Analysis on the Trend of Precipitation Change in Ningxia, Ningxia Research Institute of Meteorological Science.

24 Data from The Climate Change in Ningxia, Ningxia Meteorological Bureau.


26 Data from The Basic Condition of Ningxia’s Water Resources, Water Resources Department of Ningxia.


28 Data from The Basic Condition of Ningxia’s Water Resources, Water Resources Department of Ningxia.


30 Data from Ningxia Water Resources Bulletin (2012), Water Resources Department of Ningxia.

31 According to the United Nations, the indicator of water sustainability is the ratio between the total volume of water assumption and the quantity of local surface water. When the ratio is over one, it indicates that the water assumption has exceeded the natural recharging ability, which means it is unsustainable.

32 Calculated according to the total amount of water resources and the permanent resident population of the prefecture-level cities in Ningxia.

Data from Ningxia Water Resources Bulletin (2012), Water Resources Department of Ningxia.

Data from The Eleventh Five-Year Plan for National Economic and Social Development of Ningxia Hui Autonomous Region. Ningxia Hui Autonomous Region Government.

Data from The Twelfth Five-Year Plan for National Economic and Social Development of Ningxia Hui Autonomous Region. Ningxia Hui Autonomous Region Government.

Data from The Twelfth Five-Year Plan for National Economic and Social Development of Ningxia Hui Autonomous Region. Ningxia Hui Autonomous Region Government.

Data from The Twelfth Five-Year Plan for National Economic and Social Development of Ningxia Hui Autonomous Region. Ningxia Hui Autonomous Region Government.

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it will also set the foundation for pollutant discharge permit and the check and the
ratification of initial emissions permits, building the unified and shared basic condition
for environmental regulation.

gov.cn/sltweb/articleMsg.action?articleId=20580&channelId=31

68 Yellow River Conservancy Commission of Ministry of Water Resources,
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75 Calculated according to Ningxia Statistical Yearbook over the years.

76 Xin Yang. The Ordes City’s Practice of Water Right Transfer in the Yellow River Basin
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77 CHEN Yongqi. Practice and Exploration on Water right Transfer in the Yellow River
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78 Meng Yannin. The Magic of the “Invisible Hand” — Reports on Ningxia’s Water
chinawater.com.cn/newscenter/df/ny/20140724_355285.html

79 In May 2014, Ministry of Water Resources of P.R. China issued Notice of Conducting
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Gansu, Hubei, Jiangxi and Guangdong to conduct water right plotting work. Ningxia is
designated to pilot water entitlement which is the basis for water right trading.

80 Data from The Current Condition of Ningxia’s Water Resources Fee, Water Resources
Department of Ningxia.

81 Data source: http://www.nxnews.net/sz/system/2013/12/17/010974608.shtml

82 Notice of Several Issues Regarding the Standards of Water Resources Fee, NDRC
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83 The Water Price Channel of the China Water Website: http://price.h2o-china.com/

84 Measures for Ningxia Hui Autonomous Region’s Implementation of “Provisions on
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85 Provisions on the Utilization of Mineral Resources Compensation Fees in Ningxia
Hui Autonomous Region, Issued by the Finance Department of Ningxia and Land and
Resources Department of Ningxia[2002]No.221

86 Ningxia developed six projects on mine management in 2010. The six projects are
located in the Huidong mining subsidence area in Shizuishan, the Beibao gravel mining
area near Helan Mountain in Donggu County, Yinchu City, the Hului sand mining
area in Xiji County, the Haizitang gravel mining area in Hongsibao, the Yanjiatan mining
area in Yongkang County, Zhongwei and the Donglu gravel mining area near Niushou
Mountain in Wuzhong.

87 Taking thermal power generation as an example, The Comprehensive Water
Resources Management Plan for Ningxia estimates that Ningxia’s thermal power
installed capacity will reach 25,480,000 kilowatts by 2020 while The Twelfth Five-Year
Plan for Ningxia’s Energy Development requires its thermal power installed capacity to
reach 30,000,000 kilowatts by the end of 2015.

88 Relevant contents from The Notice on Starting the Pilot Program on Water Right.

89 Calculated according to The Statistical Bulletin of the National Economic and Social
Development of the Ningxia Hui Autonomous Region in 2012 and The Domestic Water
Quota in Urban Ningxia (issued by People’s Government of Ningxia in The Notice of
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No.182).

90 The Notice on the Local Taxation Departments’ Collection of Water Resources Fee
for Mining Industry, issued by the General office of Shanxi People’s Government[2011]
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92 http://www.nxgtt.gov.cn/info/news/Content/7471.htm

93 Calculation methods and data sources of Aqueduct: Gassert, F., M. Landis, M. Luck,
aqueduct-metadata-global-maps-20

94 Raster here refers to the grids that evenly divides the earth’s surface. Each grid cell
is a pixel with row and column number, and contains information of the pixel’s attribute
type or value, or a pointer for its attribute record. 1 degree or 0.25 degree raster
indicates that the earth’s surface is divided into 1 degree or 0.25 degree grids evenly.

95 Currently GLDAS-2.1 can provide data from 2000 till now: http://hydro1.sci.gsfc.
nasa.gov/data/s4pa/GLDAS/README,GLDAS2.pdf

http://www.wri.org/publication/aqueduct-metadata-global-
Runoff from the official record is described as the quantity of surface water resources. Official record states that the runoff records are measured by river gauges or estimated if there are water consumption and/or diversion upstream.

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