China and US Case Studies: Preparing for Climate Change

Beijing: Preparing for Water Scarcity and Drought

Mia Lu and Joanna Lewis

China-US Case Studies Project: This report is part of a series of six case studies (http://www.georgetownclimate.org/US-China-case-studies) that explore how subnational actors (municipalities, states, and special administrative regions) in the United States and China are building resilience to natural hazards, extreme weather, and climate change. These case studies examine efforts to adapt to impacts in three U.S. and three Chinese jurisdictions, including efforts to prepare for: (i) increasing coastal flooding due to more frequent and intense coastal storms and rising sea levels in coastal Louisiana and Shanghai; (ii) increasing water scarcity in Austin, TX, and Beijing; and (iii) increasing heat waves and urban heat islands in Washington, DC, and Hong Kong. These case studies are oriented toward building resilience to the weather and climate related impacts being experienced in each jurisdictions; these actions are not always explicitly linked to climate change, and we do not evaluate the effectiveness or appropriateness of the specific activities undertaken by each jurisdiction.

These case studies were supported by a grant from the Georgetown Environment Initiative and the MacArthur Foundation. The Georgetown Climate Center collaborated with Professor Joanna Lewis at Georgetown University's Edmund A. Walsh School of Foreign Service on this interdisciplinary comparative research.

Introduction

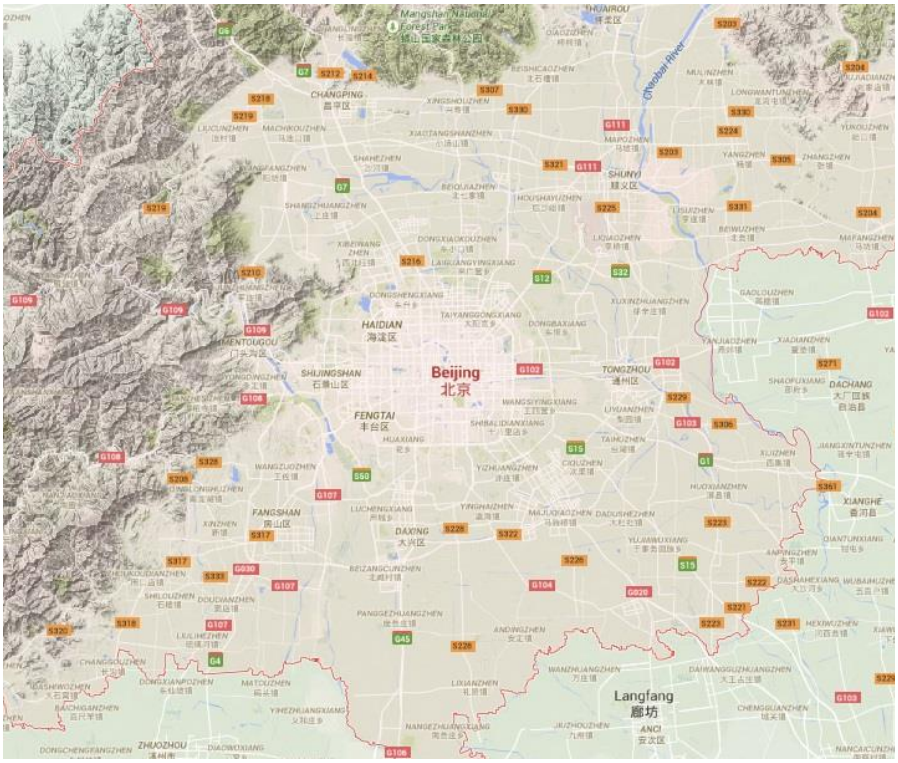
China's capital city of Beijing is already facing a serious water scarcity challenge, which is projected to only get worse with a warming climate. Water consumption in this city of 20 million people far exceeds local supply, and per capita resources place the city below the UN water scarcity threshold and in a position of more severe water scarcity than even much of the Middle East.[1] While declining surface and groundwater and increasing population—along with widespread water pollution—drive current water scarcity, expanded drought occurrences in Northern China are further constraining Beijing's water supply. In response, the Chinese Central government has initiated a multibillion "South to North" water diversion project (*Nanshuibeidiao*), which began operation in late 2014.[2]

[1] China Dialogue, "Beijing Water Shortage Worse than the Middle East," *China Dialogue*, August 29, 2013, https://www.chinadialogue.net/article/show/single/en/6319-Beijing-water-shortage-worse-than-the-Middle-East; UN, "International Decade for Action 'Water for Life' 2005-2015. Focus Areas: Water Scarcity," November 24, 2014, http://www.un.org/waterforlifedecade/scarcity.shtml.

[2] Lily Kuo, "China Has Launched the Largest Water-Pipeline Project in History," *The Atlantic*, March 7, 2014, http://www.theatlantic.com/international/archive/2014/03/china-has-launched-the-largest-water-pipeline-project-in-history/284300/; Jonathan Kaiman, "China's Water Diversion Project Starts to Flow to Beijing," *The Guardian*, December 12, 2014, http://www.theguardian.com/world/2014/dec/12/china-water-diversion-project-beijing-displaced-farmers.

Background

Beijing, the capital city of China, is located on the North China Plain, with the Yan Mountain to the North and Taihang Mountain lying to the West of the city. Beijing has a typical continental monsoon climate in that 80 percent of its precipitation is concentrated from June to September.[3] Since there is little rainfall in other months, the city is vulnerable to droughts in dry seasons.



Map of Beijing
Source: Google maps

Climate change is likely exacerbating the already challenging water scarcity situation in Beijing. According to "China's Policies and Actions for Addressing Climate Change," published by the Information Office of China's State Council in 2011, heat waves, droughts, floods and other extreme climate conditions have occurred more frequently, making the impact of climate change increasingly prominent.[4] Since 1999, Beijing has had more "Cooling Degree Days"[5] than historical trends, and has experienced frequent droughts with fewer rainy days and lower precipitation intensity.[6] According to the National Meteorological Center

[3] Youquan Zhang et al., "Characterization of Land Subsidence Induced by Groundwater Withdrawals in the Plain of Beijing City, China," *Caracterización de La Subsidencia Del Terreno Inducida Por La Extracción de Agua Subterránea En La Planicie de La Ciudad de Beijing, China.* 22, no. 2 (March 2014): 397–409.

[4] Information Office of the State Council The People's Republic of China, "China's Policies and Actions for Addressing Climate Change," November 2011, http://www.scio.gov.cn/zfbps/gqbps/2011/Document/1052763/1052763.htm.

[5] A cooling degree day is a unit used to relate the day's temperature to the energy demands of air conditioning. Cooling degree days are calculated by subtracting 65 from a day's average temperature. For example, if the day's high is 90°F and the day's low is 70°F, the day's average is 80°F. Eighty minus 65 is 15 cooling degree days. From: http://usatoday30.usatoday.com/weather/resources/askjack/waskdays.htm.

[6] Jiaqi Zhai, Yong Zhao, and Yuansheng Peng, "Long-Term Drought Evolution Laws and Its Trend Predication in Beijing Region北京地区干旱长期演变规律及未来趋势预测," *Water Resources and Power* 30, no. 3 (March 2012).

(NMC), in early 2011 Beijing had no precipitation for 108 consecutive days for the first time in the past 60 years.[7] Historically, the average annual precipitation in Beijing reached 595 mm (23.4 inches), but the past three decades have seen levels of less than 430 mm (16.9 inches), with a low in 2008 of only 207 mm (8.15 inches) of rainfall.[8]

Overall water supply is declining, driven by less precipitation to replenish reservoirs and wells. In addition, water demand is increasing, driven by increasing population and the expansion of development in Beijing municipality. Per capita water resources in Beijing are less than 200 m^3. The United Nations defines water scarcity as less than 1000 m^3 per capita, which means Beijing has less than 1/5 of the minimum requirement.[9] Therefore, water scarcity, accelerated by climate change, will likely be a major challenge for Beijing in the years to come.

Efforts to Address Water Scarcity

The Chinese central government and the Beijing municipal authorities, along with several international organizations that work in China, are undertaking a variety of actions to address the problem of water scarcity. While few of these actions were taken as direct adaptation responses to climate change, most are the type of responses that will be necessary as climate-related stressors on water resources increase.

The Municipal Government

The Beijing municipal government has implemented various strategies and policies to deal with drought and water shortage. In order to reduce water demand in the agricultural sector, the largest consumer of water, the municipal government has been converting agricultural land to crops that use less water, or even changing farmland to forest. Since 2000, 7,000 hm^2 of farmland was converted from rice (a very water-intensive crop) to corn or to wheat, and 20,000 hm^2 of farmland has been converted back to forest.[10]

In order to expand supply, the municipal government has been diverting water from neighboring areas since 2003, including Yunzhou, Youyi and the Huliu River in Hebei Province, with a total of 300 million m^3 diverted each year.[11] Beijing has been pumping groundwater since the 1990s, with an average rate of 2.5 billion m^3 extracted every year,[12] and more than 6.5 billion m^3 over the past decade.[13]

---

[7] Xinhua News Agency, "Beijing to Embrace First Snow, End to Longest Winter Drought in 60 Years," accessed June 15, 2014, http://news.xinhuanet.com/english2010/china/2011-02/09/c_13724861.htm.

[8] Qingsong Li, "Questions on Beijing Water Resources北京水问," *China Territory Today*, 2010.

[9] Yong Yang et al., "Study on the Correlation between Groundwater Level and Ground Subsidence in Beijing Plain Areas北京平原区地下水水位与地面沉降关系研究," *Geotechnical Investigation & Surveying工程勘察*, no. 8 (2013): 44–48.

[10] Yuzao Nie and Cunhui Fan, "Beijing's Actions to Continuous Droughts北京市应对连续干旱的对策," *China Water Resources*, no. 11 (2010): 27–28.

[11] Ibid.

[12] Yang et al., "Study on the Correlation between Groundwater Level and Ground Subsidence in Beijing Plain Areas 北京平原区地下水水位与地面沉降关系研究," 2013.

[13] "Beijing Water Authority: The City Has Overexploited Undergound Water for 15 Years市水务局：北京地下水超采15年," *The Beijing News*, April 26, 2014, sec. Hot Topic.

Since 2003, Beijing has also introduced a program to recycle water for irrigation, road cleaning and for landscape ponds in local parks. By 2010, 1,000 decentralized wastewater reuse systems had been constructed in Beijing.[14] In 2011, the city used 1.1 billion m^3 of recycled water, which became the second largest water resource for Beijing. Recycled water utilization is estimated to reach 1.45 billion m^3 by 2020.[15]

The Central Government

The central government has intervened to help address Beijing's water scarcity challenges primarily via large, national infrastructure projects to bring water to Northern China. The multibillion dollar "South to North" water diversion project (*Nanshuibeidiao*) is scheduled to begin transferring water from the Danjiangkou Reservoir in Hubei province to Beijing in December 2014. Although this massive project was not primarily motivated by climate change, it could significantly reduce the water scarcity challenges faced by northern China, especially as droughts become more frequent and more extreme given climate change projections.

The construction of the Middle Route Project (MRP), the route that mainly delivers water to Beijing, started in December 2003. The portion of the project that was completed in December 2014 transports about 9.5 billion m^3 of water annually from central to northern China, including the cities of Beijing and Tianjin, and consists of a series of canals spanning 890 miles across northeastern China. The final "Western leg" of the project, when completed, will be designed to divert about 45 billion m^3 of water annually across the country.[16] It is estimated that construction costs for the project to date total approximately $80 billion.[17]

Photo of the Canals in Hubei from the South-North Water Diversion Project.
Source: http://factsanddetails.com/china/cat10/sub66/item1661.html

[14] Xiao Liang and Meine Pieter van Dijk, "Financial and Economic Feasibility of Decentralized Wastewater Reuse Systems in Beijing.," *Water Science & Technology* 61, no. 8 (April 15, 2010): 1965–73.

[15] Zhenhua Sun, Mingbo Cheng, and Yiyang Zhang, "Situation and Management Strategy of Water Resources in Beijing北京市水资源形势与对策," *Beijing Water*, no. 4 (2013): 8–11.

[16] Christina Larson, "World's Largest River Diversion Project Now Pipes Water to Beijing," *BloombergView*, December 15, 2014, http://www.bloomberg.com/bw/articles/2014-12-15/world-s-largest-river-diversion-project-now-pipes-water-to-beijing.

[17] For a map of the South North Water Transfer project see Michael Bristow, "Moved to Quench the Thirst," *BBC*, March 3, 2010, sec. Asia-Pacific, http://news.bbc.co.uk/2/hi/asia-pacific/8545321.stm.

International Organizations

Numerous international and multilateral institutions have engaged with China to address the impacts of climate change, [18] and water scarcity in particular. For example, the United Nations International Strategy for Disaster Reduction established the International Center for Drought Risk Reduction (Drought Center) in Beijing, cosponsored by the National Disaster Reduction Center of China. The Drought Center's mandate is to promote the exchange of drought relief information and spread drought risk reduction technologies through training.[19]

In addition, the World Bank has brought many new irritation technologies to Northern China to reduce agricultural water use.[20] Such initiatives, combined with government policies, have targeted agricultural water conservation. In past decades, Chinese farmers have primarily used canal irritation, but in recent years more than 60 percent of them have switched to sprinkler irritation, low flow irritation, and fertilization. As a result, agricultural water usage dropped from 1.7 billion m^3 in 2001 to 1.32 billion m^3 in 2010, a decrease of 24 percent.[21]

Lessons Learned

Municipal, national, and international stakeholders have been engaged in actions to address water scarcity in Beijing. While these initiatives were not necessarily motivated by climate change, Beijing has been a leader within China in undertaking carbon mitigation policies, and is the site of one of the first pilot carbon emissions trading programs in the country. Other cities facing similar challenges in China and around the world could learn from Beijing's experiences with recycled water systems and large-scale water diversion. Beijing's actions to address water scarcity have also come with major challenges, which too may provide lessons to others looking to avoid the same mistakes.

Overexploitation of Groundwater

First, groundwater has contributed to more than 60 percent of total water supply in Beijing, one of very few big cities that rely so heavily on groundwater resources. The over-extraction of groundwater has created to at least five major land subsidence areas in Beijing, centered in the Chaoyang, Huairou and Changping districts. By 2010, the total area of land experiencing subsidence of greater than 50mm was over 4281 m^2, or about 67 percent of the total land area of the Beijing Plain.[22] The rate of land subsidence has been shown to be highly correlated with the rate of groundwater extraction.[23] With 15 years of over-

[18] Information Office of the State Council The People's Republic of China, "China's Policies and Actions for Addressing Climate Change 2013," Government White Paper (Beijing, November 2013).

[19] Xinhua News Agency, "China Joins UN to Fight Global Drought," April 3, 2007, http://www.china.org.cn/english/environment/205882.htm.

[20] Nie and Fan, "Beijing's Actions to Continuous Droughts北京市应对连续干旱的对策."

[21] Hong Ye, Yiyuan Li, and Xia Jin, "Survey of Influences of Droughts on People Living in Rural Beijing for the Past Three Decades近30年北京地区干旱化对京郊人民生活生产的影响调查," *Science Times科学时报*, December 1, 2010, sec. B4, http://news.sciencenet.cn/sbhtmlnews/2010/11/239187.html.

[22] Yang et al., "Study on the Correlation between Groundwater Level and Ground Subsidence in Beijing Plain Areas北京平原区地下水水位与地面沉降关系研究," 2013.

[23] Yan Yang et al., "Analysis and Outlook of the Land Subsidence in Beijing北京地面沉降工作分析及展望," *Urban Geology 城市地质* 7, no. 2 (2012): 9–13.

extraction, Beijing's groundwater level is down 12.83 m, and is continuing to decrease at a rate of one meter per year.[24] The current average groundwater depth is 24.9 meters, compared to 6.4 meters in 1978.[25]

Uncertainty Surrounding Water Imports from the South

Second, for more than a decade, Beijing has been anticipating the receipt of water from the South to alleviate its water shortage. However, there are many challenges that could greatly undermine the expectations of the diversion project. First, climate change does not only affect Beijing, but also the Yangtze River plain area. The Danjiangkou Reservoir in Hubei Province, the main reservoir for much of central China, has been facing declining water levels. Less water in the reservoir means less water will make its way to Beijing. The reservoir reached a historical low in mid-2014, causing uncertainty about the quantity of water that will be available for diversion to Beijing once the South-North water transfers begin.[26]

Finally, while Beijing has long been relying on groundwater, the water being moved from the South is surface water containing different trace elements. The two water sources will be mixed in Beijing reservoirs. The difference in trace elements may cause a problem for the water pipes in the city that are used to delivering mostly groundwater, and there also may be issues related to water quality when the water is mixed. One Professor at Beijing Normal University noted that when professionals brought water from Beijing to the Danjiangkou Reservoir and poured it in, the water turned yellow.[27] According to experts from Beijing Water Science Institute, the mixed water has a higher pH, though it is still below 8.5: the level required for drinking. When the surface water from Dajiangkou accounts for most of the mixed water, the pH is expected to rise even higher, therefore it will need to be closely monitored. [28]

---

[24] "Beijing Water Authority: The City Has Overexploited Undergound Water for 15 Years市水务局：北京地下水超采15年."

[25] Yong Yang et al., "Study on the Correlation between Groundwater Level and Ground Subsidence in Beijing Plain Areas北京平原区地下水水位与地面沉降关系研究," *Geotechnical Investigation & Surveying工程勘察*, no. 8 (2013): 44–48.

[26] Xinhua News Agency, "Water Level Dropped at Danjiangkou Reservoir of the Mi

ddle Route Project南水北调中线丹江口水库水位下降 首季蓄水落空," *China News*, January 1, 2014, http://www.chinanews.com/gn/2014/01-01/5686502.shtml.

[27] Yinchun Lan, "The Pros and Cons of Water Replenishing in Beijing北京补水利弊谈," *The Earth*, no. 9 (2012): 86–89.

[28] Licai Liu, Fandong Zheng, and Chunyi Zhang, "Characteristics of Water Quality of South-to-North Water Diversion Mixed With Groundwater in Beijing南水北调水源与北京地下水混合的水质变化特征," *Hydrogeology & Engineering Geology水文地质工程地质* 39, no. 1 (2012): 1–7.

The Georgetown Climate Center is grateful for generous support from the Georgetown Environment Initiative, the MacArthur Foundation, and the Kresge Foundation.

Prepared by Mia Lu and Joanna Lewis. Please contact Joanna Lewis (jil9@georgetown.edu; https://sfs.georgetown.edu/Joanna-Lewis) with any questions.

GEORGETOWN CLIMATE CENTER