世界资源研究所
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TECHNICAL NOTE

BASELINE WATER STRESS: CHINA

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EXECUTIVE SUMMARY

The Aqueduct Water Risk Atlas, developed by the World Resources Institute (WRI), evaluates, maps, and scores water risks globally based on 12 indicators, including baseline water stress. Baseline water stress measures the ratio between total water withdrawal and available renewable surface freshwater supply, and is a good proxy for water risks more broadly. The atlas calculates baseline water stress based on country-level water withdrawal data from the Food and Agriculture Organization of the United Nations, spatially disaggregated by sector into Aqueduct's catchment areas. Where available, however, more detailed data allow the development of a baseline water stress map for a country or region. In the case of China, freshwater withdrawal data at the prefecture level provide more accurate information, such as spatial patterns, that are otherwise lost in the aggregated country-level statistics.

In an effort to respond to the need for more granular baseline water stress maps, WRI has developed a China-specific baseline water stress indicator (BWS-China), using freshwater withdrawal data available at the prefecture level of over 300 prefectures, and spatial grid data (i.e. population, irrigated area, and factory data).

This technical note describes the data and methodology used to calculate BWS-China, building on the methodology described in previous Aqueduct publications (Shiklomanov and Rodda 2014; Gassert et al. 2013). In general, results show that Aqueduct's global baseline water stress indicator maps and BWS-China maps share similar spatial patterns. However, upon closer examination, the

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Technical notes document the research or analytical methodology underpinning a publication, interactive application, or tool.

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maps show differences in some catchments. More detailed water withdrawal data by sector used in BWS-China can reveal new spatial patterns.

The maps generated with the BWS-China data are significant on two counts:

- This is the first time that more detailed, country-specific water withdrawal data have been integrated into Aqueduct's global baseline water stress indicator, providing a useful model for other countries and stakeholders wishing to develop baseline water stress indicators in their own countries.

- While Aqueduct's global baseline water stress indicators provide useful information on spatial water risk patterns, country-specific data, when available, produce more detailed and geographically specific results.

However, for countries without more detailed data, Aqueduct's global baseline water stress indicator is still useful for assessing the overall spatial patterns of water risk.

The primary audiences for BWS-China are international and national companies with businesses in China, and Chinese government officials. While Aqueduct's global baseline water stress indicator has been used primarily by companies to assess water risk across geographic boundaries and to develop water strategies on a global scale, BWS-China can meet the needs of companies whose businesses or interests are specific to China. BWS-China can be used by these entities to evaluate investment opportunities or dig deeper into water risks facing their operations and supply chains. BWS-China can also support policymakers and decision-makers at central or local level as they assess water stress in a specific location, compare water stress between locations, and seek to understand the water stress induced by a specific sector.

BACKGROUND

The Aqueduct Water Risk Atlas uses 12 indicators to present, in visual form, the risks and opportunities associated with water availability. The baseline water stress indicator provides an overview of the total demand for freshwater from all sectors and the available annual renewable surface freshwater supply in a given place. It has attracted a large group of users, including companies, investors, researchers, nongovernmental organizations, consultants, international organizations, and governments.

Aqueduct maps the baseline water stress indicator for the whole world, using country-level freshwater withdrawal data as reported to the Food and Agriculture Organization of the United Nations (FAO) that are then spatially disaggregated by catchment area and across different use sectors (agriculture, industry, domestic). While more detailed water withdrawal or demand data (e.g. higher spatial resolution, more temporally frequent) are available in some countries, not all countries have such data, or they use different units of analysis or inconsistent methodologies. For example, in the United States, water withdrawal data are available at the county level of over 3000 counties and county equivalents while, in China, they are available at the prefecture level for 345 administrative subdivisions. Some spatial patterns can be lost when an aggregated number is used at the country level, especially when the regions within a country have distinct water withdrawal characteristics due to economic and social development differences. To reduce or avoid the loss of spatial pattern information, which is important for estimating water risk accurately, we use more detailed data for country-specific analysis when they are available.

SIMILARITIES AND DISTINCTIONS BETWEEN AQUEDUCT'S GLOBAL BASELINE WATER STRESS INDICATOR AND BWS-CHINA

WRI developed BWS-China to respond to the need for detailed country-level data on baseline water stress in China. BWS-China uses the same methodology as Aqueduct's global baseline water stress indicator (BWS-Global) to calculate water supply, "total blue water" and "available blue water."[1] However, Aqueduct's global baseline water stress indicator uses

FAO AQUASTAT country-aggregated water withdrawal data, which are then spatially disaggregated to subnational level. BWS-China uses more spatially detailed water withdrawal data that are available from official government sources.

More specifically, BWS-Global and BWS-China are similar in the following ways:

- *Unit of analysis*. BWS-China and BWS-Global are calculated at the catchment level, based on the Global Drainage Basin Database developed by Masutomi et al. (2009).

- *Surface water runoff ("total blue water")*. In BWS-Global and BWS-China, total blue water refers to surface water in nature and does not include water available because of human activities (e.g. inter-basin water transfer) or groundwater. The runoff data used to model total blue water in BWS-Global and BWS-China are based on modeled data from the U.S. National Aeronautics and Space Administration for the years 1950–2010 (NASA 2012).

- *Consumptive use ratio*. This is the ratio between the portion of water that evaporates or is incorporated into a product and no longer available for downstream use, and total blue water. BWS-Global and BWS-China both adopt the consumption ratio numbers developed by Shiklomanov and Rodda (2004).

- *Available surface water supply ("available blue water")*. The methodology used in BWS-China is based on the methodology used in BWS-Global. Baseline water stress is calculated as the ratio of total water withdrawals and available blue water at the catchment level annually. Available blue water is flow-accumulated runoff minus upstream consumptive use at the catchment level. For a comprehensive overview of the methodology used to estimate total blue water, available blue water, and consumptive use water, see Gassert et al. (2013) and Gassert et al. (2015).

BWS-Global and BWS-China differ primarily in the following ways:

- *Sources of water withdrawal data*. BWS-Global uses water withdrawal data from the FAO AQUASTAT dataset. BWS-China uses data published by the Chinese government.

- *Resolution of water withdrawal and consumption data*. Water withdrawal and consumption data used in BWS-Global are at the country level, while these data in BWS-China are at the prefecture level (345 in total).

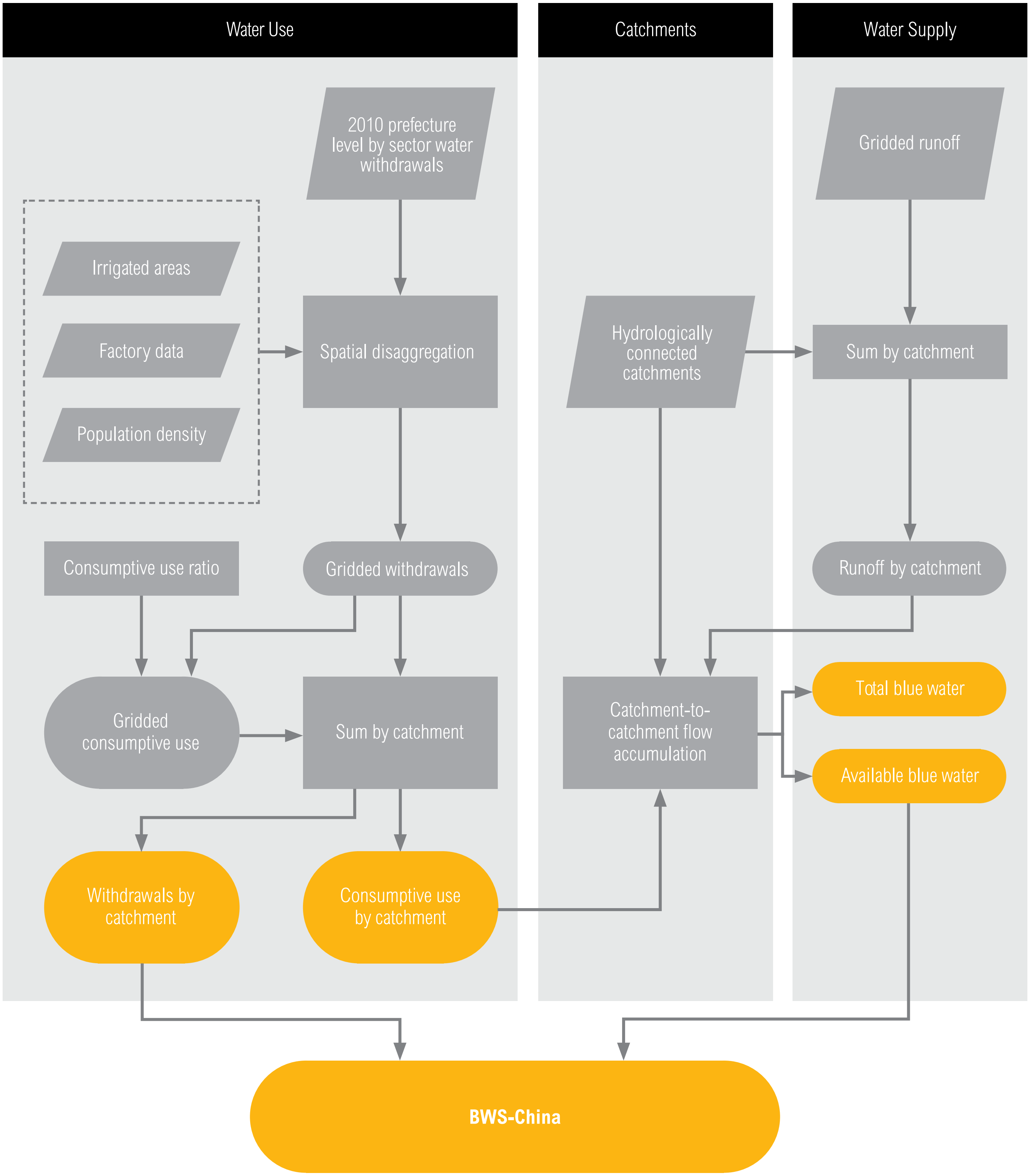
- *Irrigated agriculture withdrawal disaggregation*. BWS-Global spatially disaggregates irrigated agricultural areas using the FAO's Global Map of Irrigation Areas dataset (at 5 arc minute resolution). BWS-China uses data from the National Land Use/Cover Database of China (at 1 square kilometer resolution).

- *Industrial withdrawal disaggregation*. BWS-Global spatially disaggregates industrial withdrawals using nighttime lights from the U.S. National Oceanic and Atmospheric Administration's (NOAA's) Nighttime Lights Annual Composites datasets (at 30 arc second resolution). BWS-China uses industry factory data from the Chinese Industrial Enterprises Database (at 1 square kilometer resolution).

- *Domestic withdrawal disaggregation*. BWS-Global uses population count grid (future estimates) from the Gridded Population of the World dataset (at 2.5 arc minute resolution), and the nighttime lights dataset (at 30 arc second resolution). BWS-China uses population density grids from the Chinese Census (at 1 square kilometer resolution).

Figure 1 is a conceptual schema adapted from Aqueduct's water supply and use model schematic, showing the workflow underlying the BWS-China indicator. On the water use side, water withdrawal data by sector are collected at the prefecture level and disaggregated first to a fine resolution grid then summed by catchment. On the water supply side, gridded runoff data are summed by catchment. Baseline water stress is calculated at the catchment level using water supply and water use data.

Figure 1 | **BWS-China Workflow**



Note: Parallelograms are inputs, rectangles with straight corners are processes, and rectangles with rounded corners are outputs. The two final catchment-scale water-use metrics and two water-supply metrics are highlighted in yellow.

WATER WITHDRAWAL DATA FOR BWS-CHINA

To construct BWS-China, we used two metrics of water use: water withdrawal and consumptive use.

Water withdrawal is the total amount of water abstracted from freshwater sources for human use. We derived the water withdrawal data by sector (domestic, industrial, and agricultural) from the Chinese Water Resources Bulletin—a yearly collection of water resource data published by the Water Resources Department in each province. Water withdrawal data are collected from surveys reported by source and representative sampling, and compiled for each prefecture as a whole. (There are 345 prefectures in China, excluding Hong Kong, Macau, and Taiwan.) In contrast, BWS-Global uses sectoral water withdrawal data at the country level.

Consumptive use is the portion of water that evaporates or is incorporated into a product, and no longer available for downstream use. Consumptive use is derived from total withdrawal based on ratios of consumptive use to withdrawal developed by Shiklomanov and Rodda (2004).

WATER WITHDRAWAL DISAGGREGATION BY SECTOR

Following the same analytical methodology as BWS-Global, water withdrawals for the year 2010 are disaggregated by sector based on spatial datasets (Table 1). All spatial datasets used had a resolution of 1 square kilometer.

The spatial disaggregation by sector is described below.

Agricultural Water Withdrawal Disaggregation

Agricultural water withdrawals were disaggregated using irrigated areas data. The irrigated areas were derived from the National Land Use/Cover Database of China, developed by the Institute of Remote Sensing and Digital Earth (RADI) under the Chinese Academy of Sciences. The National Land Use/Cover Database of China is at 1:100,000 scale and contains Chinese land use/cover data for five periods (1980s, 1995, 2000, 2005, and 2010) (Zhang et al. 2014). This database was developed from medium resolution satellite images with an original resolution of 30 meters. Land use/cover types were visually interpreted and field surveys were conducted

Table 1 | **Explanatory Variables for Spatial Disaggregation by Sector**

Sector	Variable	Dataset	Year	Source	Link
Agricultural	Irrigated Areas	National Land Use/ Cover Database of China	2010	Data Center for Resources and Environmental Sciences, Chinese Academy of Sciences	http://www.resdc.cn
Industrial	Industry factory locations and their gross output	Chinese Industrial Enterprises Database	2008 to 2009	Survey Research Center, Institute for Advanced Research at Shanghai University of Finance and Economics	http://iar.shufe.edu.cn/structure/src/xxsjfw_95247_1.htm
Domestic	Population density	6th National Population Census of China	2010	National Bureau of Statistics of People's Republic of China	http://www.stats.gov.cn/english/Statisticaldata/CensusData/rkpc2010/indexch.htm.
		Built-up Areas	2010	Data Center for Resources and Environmental Sciences, Chinese Academy of Sciences	http://www.resdc.cn

to verify the classification results. The land use/cover data were then aggregated to a 1 square kilometer grid. Irrigated areas data from the year 2010 were used for the agricultural water withdrawal disaggregation.

Industrial Water Withdrawal Disaggregation

A major distinction between BWS-China and BWS-Global is the methodology for industrial water withdrawal disaggregation.

BWS-Global uses nighttime lights to identify areas of industrial activity, which are then used to spatially disaggregate industrial water withdrawals. This allows for consistent disaggregation where more detailed spatial data on industry are not available.

In China, more detailed and geographically specific datasets containing industry factory locations and their gross output are available. BWS-China uses these data to disaggregate industrial water withdrawals. The industry factory location data are from 2008 and 2009, which are the latest years available, and are close to matching the water withdrawal data from 2010. The one-to-two-year difference between the industrial water withdrawals and industry factory datasets is assumed not to have a significant effect on the model outputs.

The industry factory data were developed from the Chinese Industrial Enterprises Database. In total, there are 314,539 industries with annual revenues of 5 million yuan or more from their main business operations factories; each has attributes of factory name, sector, tax, and gross industrial output. The total production from these enterprises accounts for 90 percent of total Chinese industrial production (Nie et al. 2012). The factory data were first identified and located on the map as points. Then, the raw point layer of factories was overlaid with a 1 square kilometer grid of China to derive grid-level industrial gross output. The gross value of industrial production at the grid level was then calculated by aggregating the industrial gross output of factories within each grid cell. The gross value of industrial production (unit: thousand yuan) was used to spatially distribute industrial water withdrawals.

The method described above neglects varying water use efficiency among different subsectors and businesses. We will attempt to account for these factors in the next version of BWS-China.

Domestic Water Withdrawal Disaggregation

Domestic water withdrawals were disaggregated using population density data. The population density data at 1 square kilometer were derived from two layers. One layer was the population density in 2010 at the township level, from the 6th National Population Census of China (Wu et al. 2015; Mao et al. 2015). There are 39,007 townships in China.

The second layer was the built-up areas in 2010. The data were collected from the Institute of Geographical Science and Natural Resources under the Chinese Academy of Sciences. The built-up areas were identified using remote sensing images and field surveys. A grid was regarded as being inside a township if its center point was within or intersected by the township polygon. For each township, the population was allocated into the 1 square kilometer grids with built-up areas, according to the proportion of built-up area within each grid. Grids with no built-up area are associated with a population of zero. The grids of population density were then used to spatially disaggregate domestic water withdrawals.

TOTAL WITHDRAWAL

Total withdrawal is the total amount of water removed from freshwater sources for human use. Sectoral water withdrawals, estimated at 1 square kilometer grid scale, as described above, were aggregated within their catchments. The total withdrawal is the sum of agricultural, industrial, and domestic water withdrawals. Figures 2, 3, and 4 display total catchment-level water withdrawal intensity in the agricultural, industrial, and domestic sectors, respectively. Figure 5 displays total water withdrawal intensity (all sectors) at the catchment level.

Figure 2 | **Agricultural Water Withdrawal Intensity (2010)**

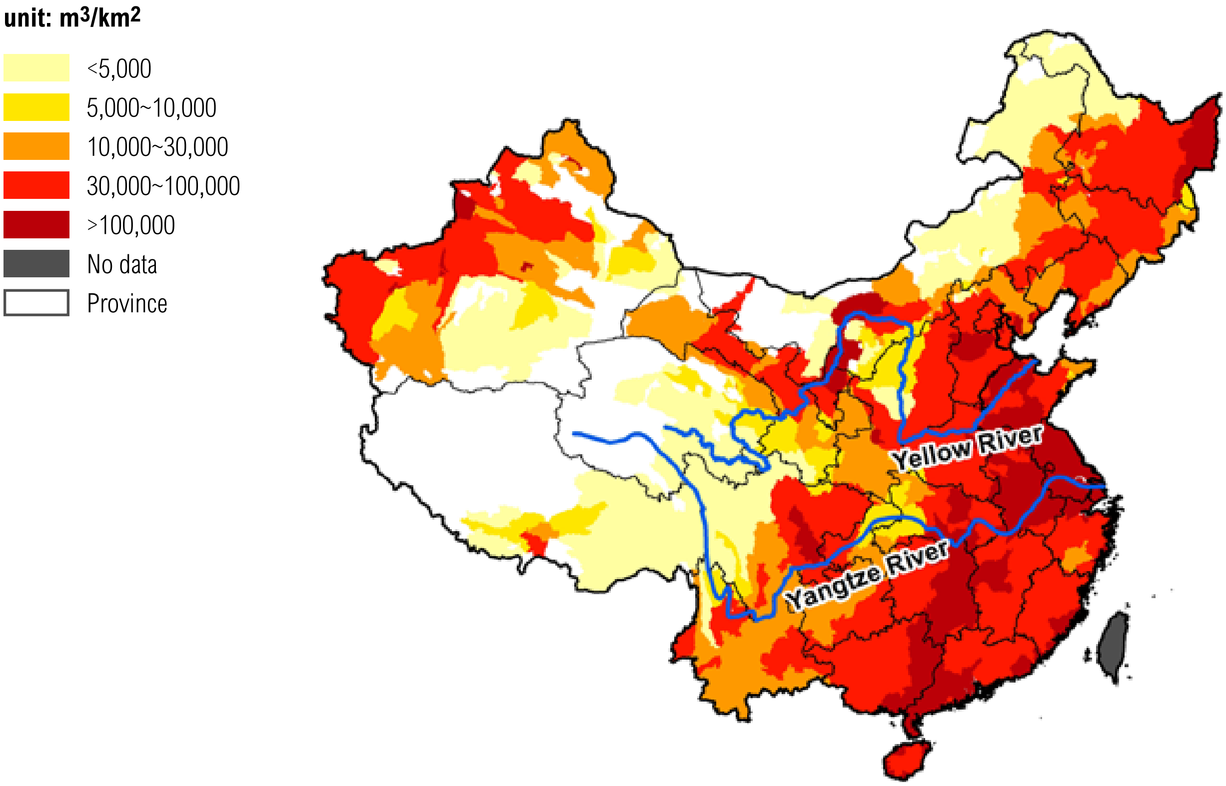


Figure 3 | **Industrial Water Withdrawal Intensity (2010)**

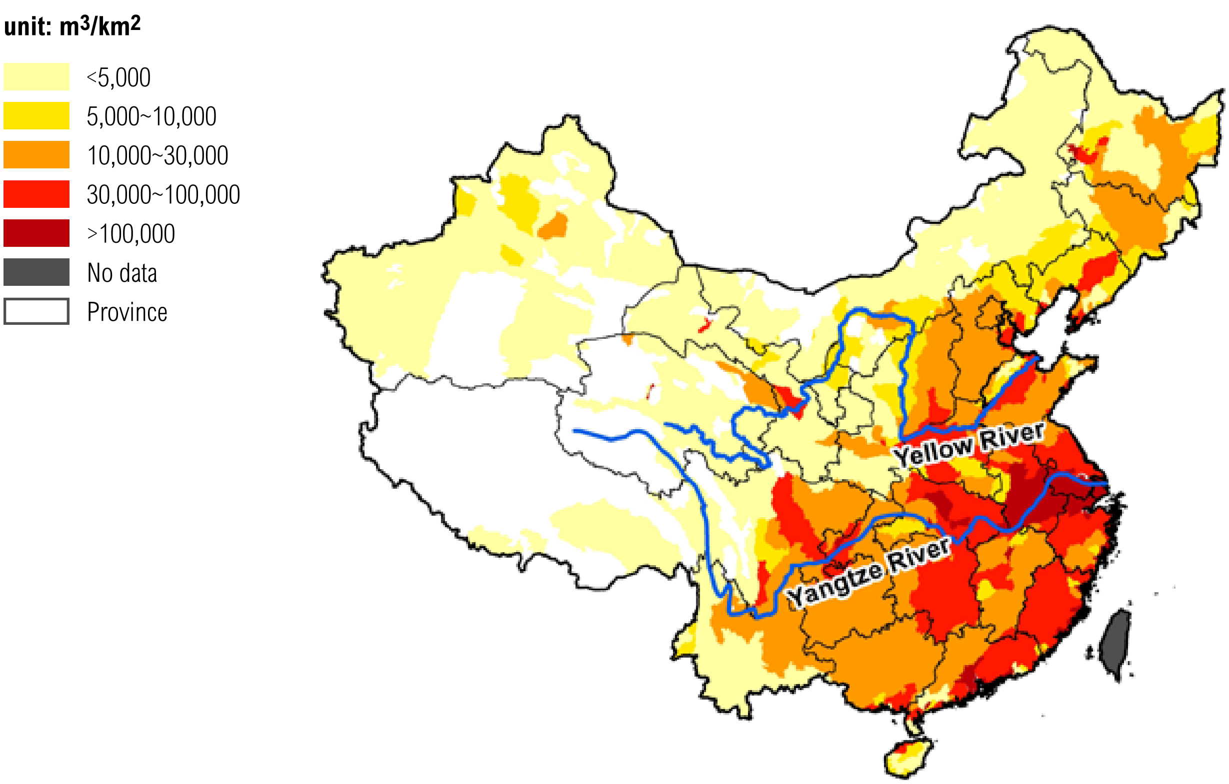


Figure 4 | **Domestic Water Withdrawal Intensity (2010)**

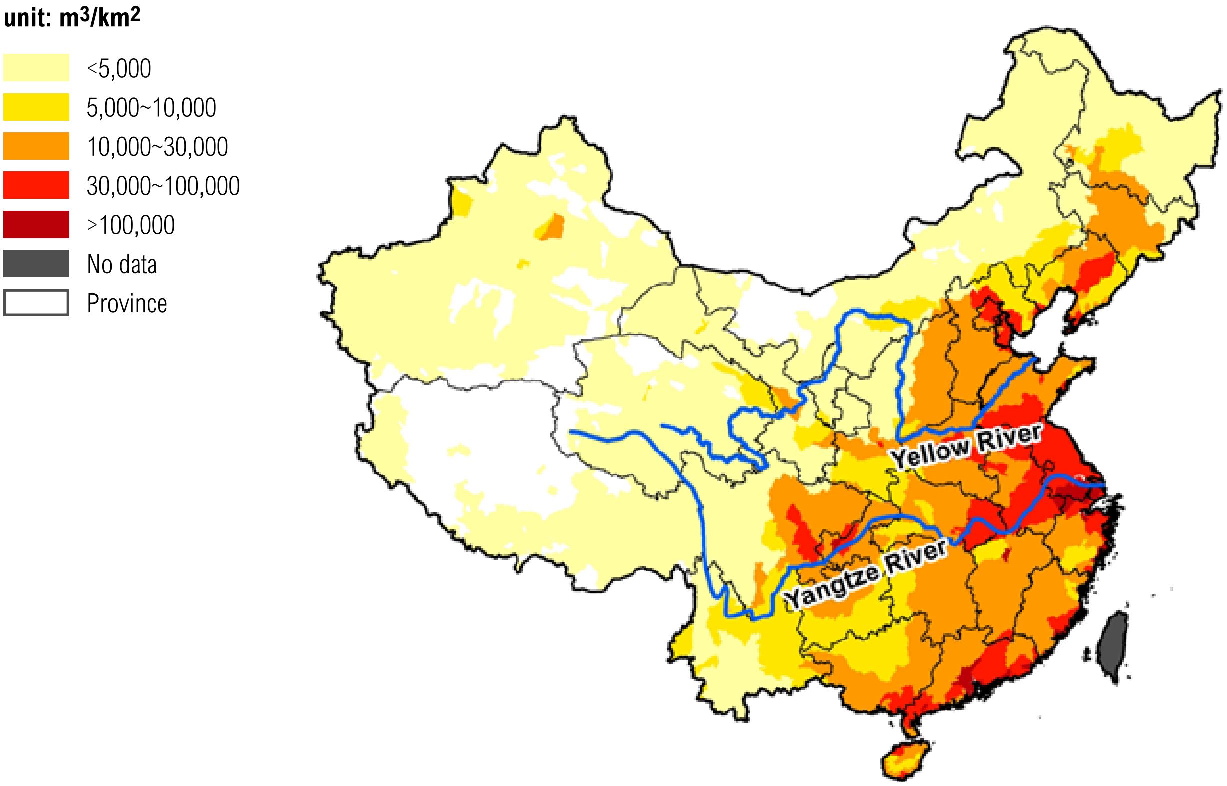
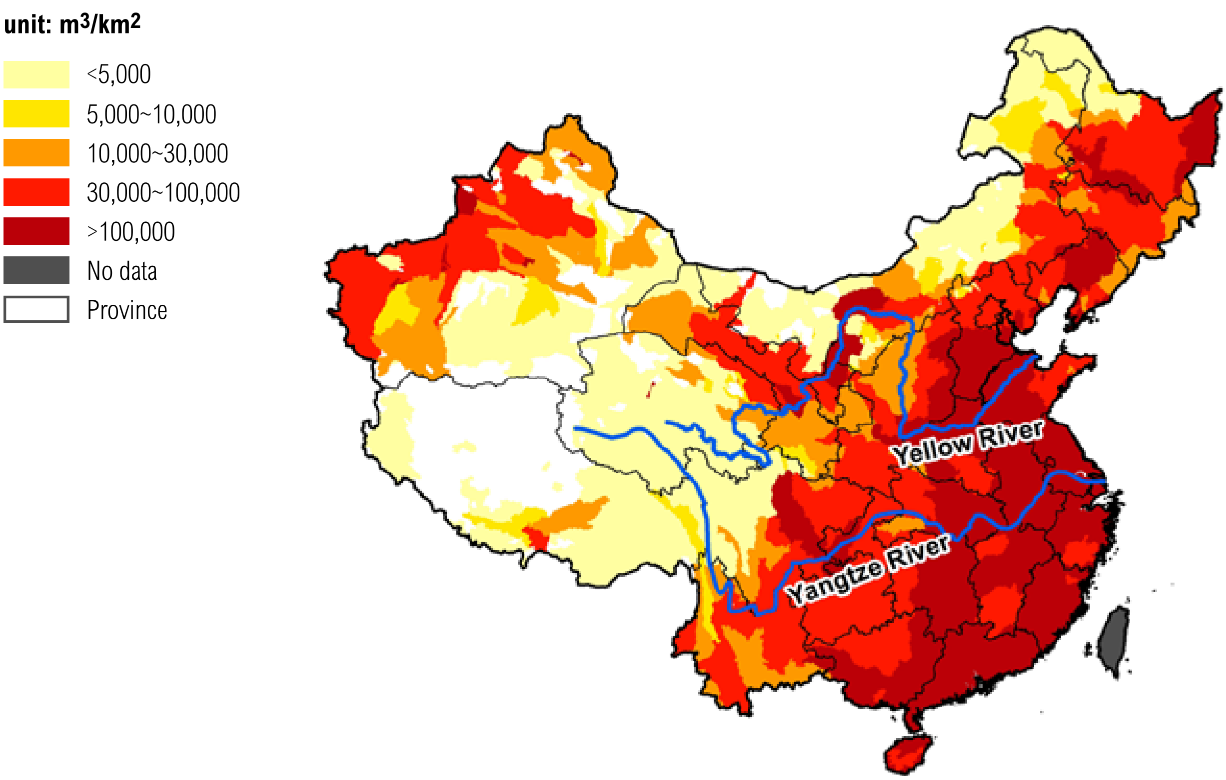


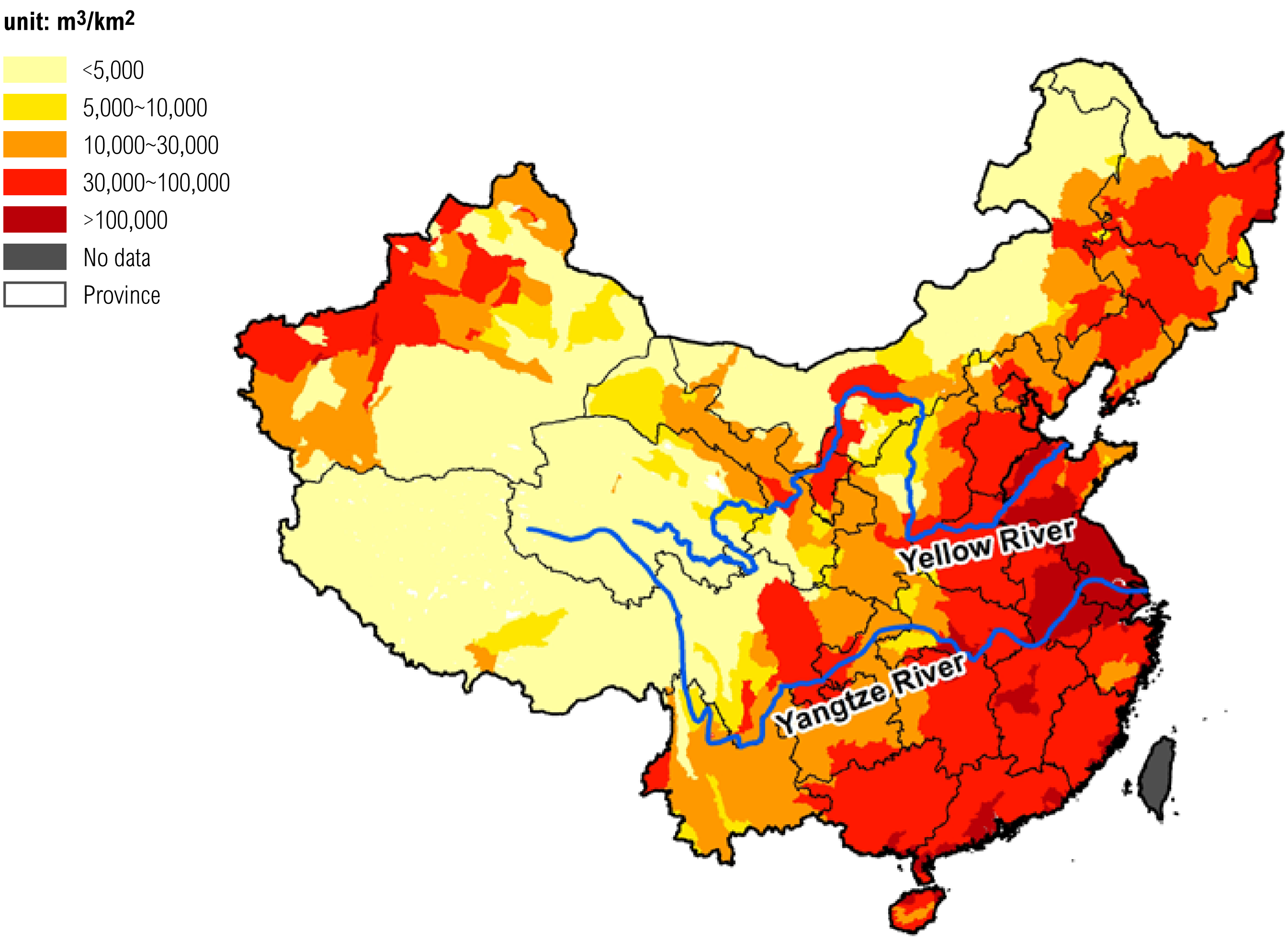
Figure 5 | **Total Water Withdrawal Intensity (all sectors, 2010)**



CONSUMPTIVE USE

Consumptive use is the proportion of all water withdrawn that is consumed through evaporation or incorporation into a product, or polluted, and is therefore no longer available for reuse. Consumptive use by sector is estimated from total withdrawal using consumptive-use ratios developed by Shiklomanov and Rodda (2004). Figure 6 displays consumptive use intensity at the catchment level.

Figure 6 | **Consumptive Use Intensity (2010)**



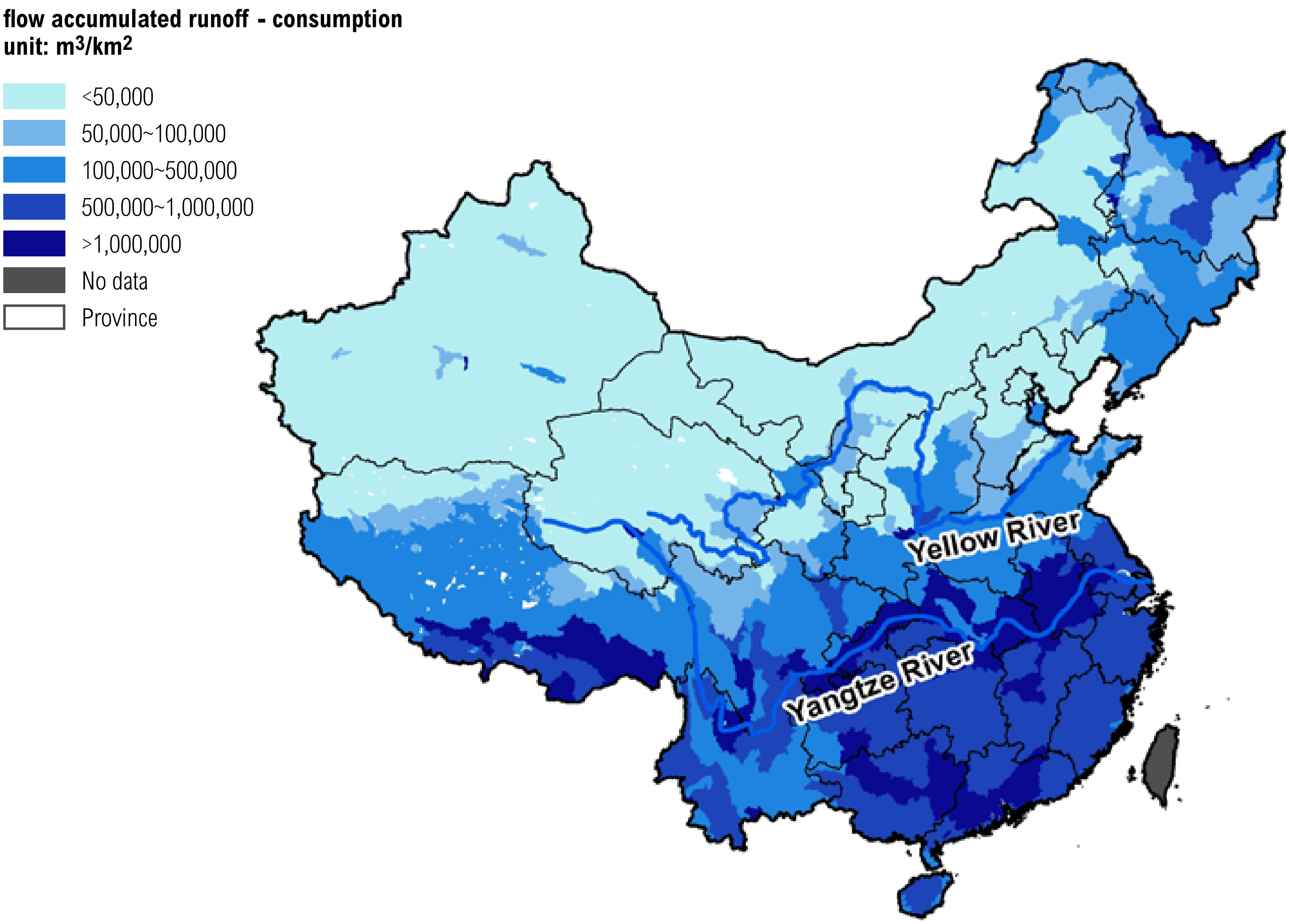
AVAILABLE BLUE WATER

Available blue water (Ba) is the total amount of water available to a catchment before any is withdrawn for use. It is calculated as all runoff water from upstream catchments minus upstream consumptive use plus runoff in the catchment. Ba is calculated as $Ba(i)=R(i)+\sum Qout(iup)$ where *R* is runoff, *Qout* is the volume of water exiting a catchment to its downstream neighbor: $Qout(i) = max(0, Ba(i)-Uc(i))$, *Uc(i)* is the consumptive use. Negative values of *Qout* are set to zero (Gassert et al. 2013).

There are 14 basins (accounting for about 1 percent of China's total land area) along the border of northeastern China and Russia with upstream flow from Russia. *Ba* for these 14 basins was adopted from BWS-Global.

Figure 7 displays available blue water intensity at the catchment level.

Figure 7 | **Available Blue Water Intensity (2010)**

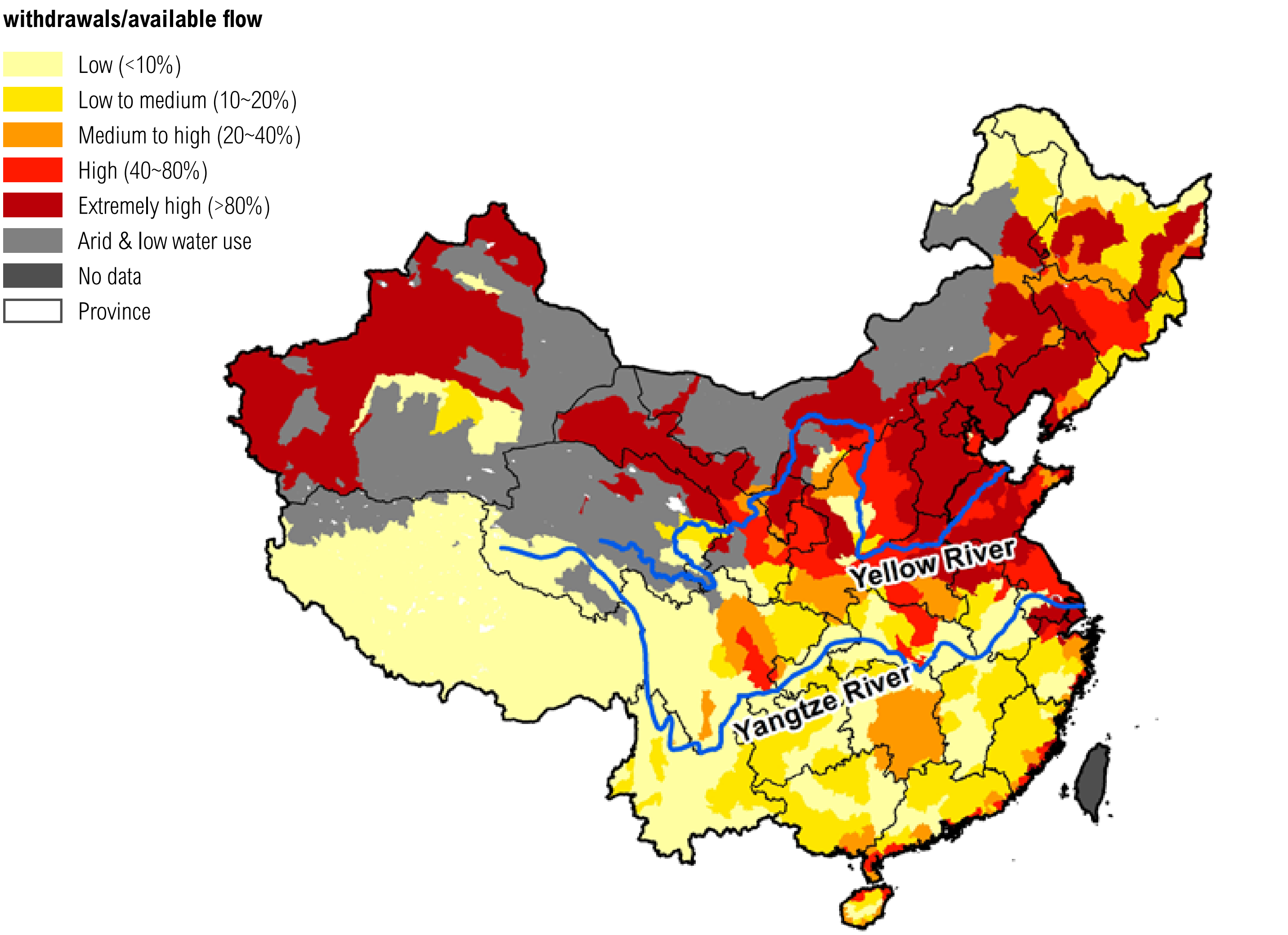


BASELINE WATER STRESS CHINA

Baseline water stress is calculated as the annual water withdrawals (domestic, industrial, and agricultural) divided by the mean of available blue water (surface). Baseline water stress is a measurement of the chronic level of competition and depletion of available water, and is a good proxy for measuring water risks more broadly (CEO Water Mandate 2014). A higher value indicates more competition for water among users and depletion of water resources.

These ratio values were grouped into baseline water stress classifications based on the methodology used in BWS-Global: low (<10%), low to medium (10–20%), medium to high (20–40%), high (40–80%), and extremely high (>80%). In BWS-China, baseline water stress was calculated for the year 2010 as the total water withdrawals from 2010 divided by mean available blue water. A long time series of runoff data from 1950 to 2010 was used to reduce the effect of multi-year climate cycles and the complexities of short-term water storage (e.g., dams, floodplains) (Gassert et al. 2015). Consistent with the BWS-Global classification, areas with available blue water and water withdrawals of less than 0.03 and 0.012 m/m^2, respectively, were classified as arid and low water use areas (Gassert et al. 2013). Figure 8 displays baseline water stress at the catchment level. The white patches located within grey areas (i.e. arid and low water use) are lakes and ponds that are not delineated as a catchment in the Global Drainage Basin Database dataset.

Figure 8 | **Freshwater Baseline Water Stress China (2010)**



DISCUSSION

Spatial and withdrawal data accuracy

As noted earlier, many data used in BWS-China were from surveys (e.g. the Chinese Industrial Enterprises Database) and public records (e.g. the Water Resources Bulletin) published by the Chinese government. To the best of our knowledge, these scientific and official government datasets provide the best spatial and water withdrawal data available at high resolution for China nationally. We are unable to independently verify or validate each dataset and we assume they are trustworthy and accurate.

Important caveats about available blue water in baseline water stress calculations

Water supply data in BWS-China include only surface water, and do not include human activities (e.g. inter-basin water transfers) that may augment or remove naturally available water to other catchments. BWS-China does not include groundwater, though in many places groundwater may be an important source of water supply. Therefore, BWS-China does not reflect the complete water supply that may be available for human use in a given catchment and some catchments may have lower baseline water stress than indicated by BWS-China. Major inter-basin water transfers and available groundwater resources will be taken into consideration in the next version of BWS-China.

Comparing results: BWS-Global vs. BWS-China

Figure 9 displays maps generated with BWS-China and BWS-Global data. The maps share similar spatial patterns, and, as expected, both show that the relatively arid northern region of China experiences more stress than China's wetter southern regions.

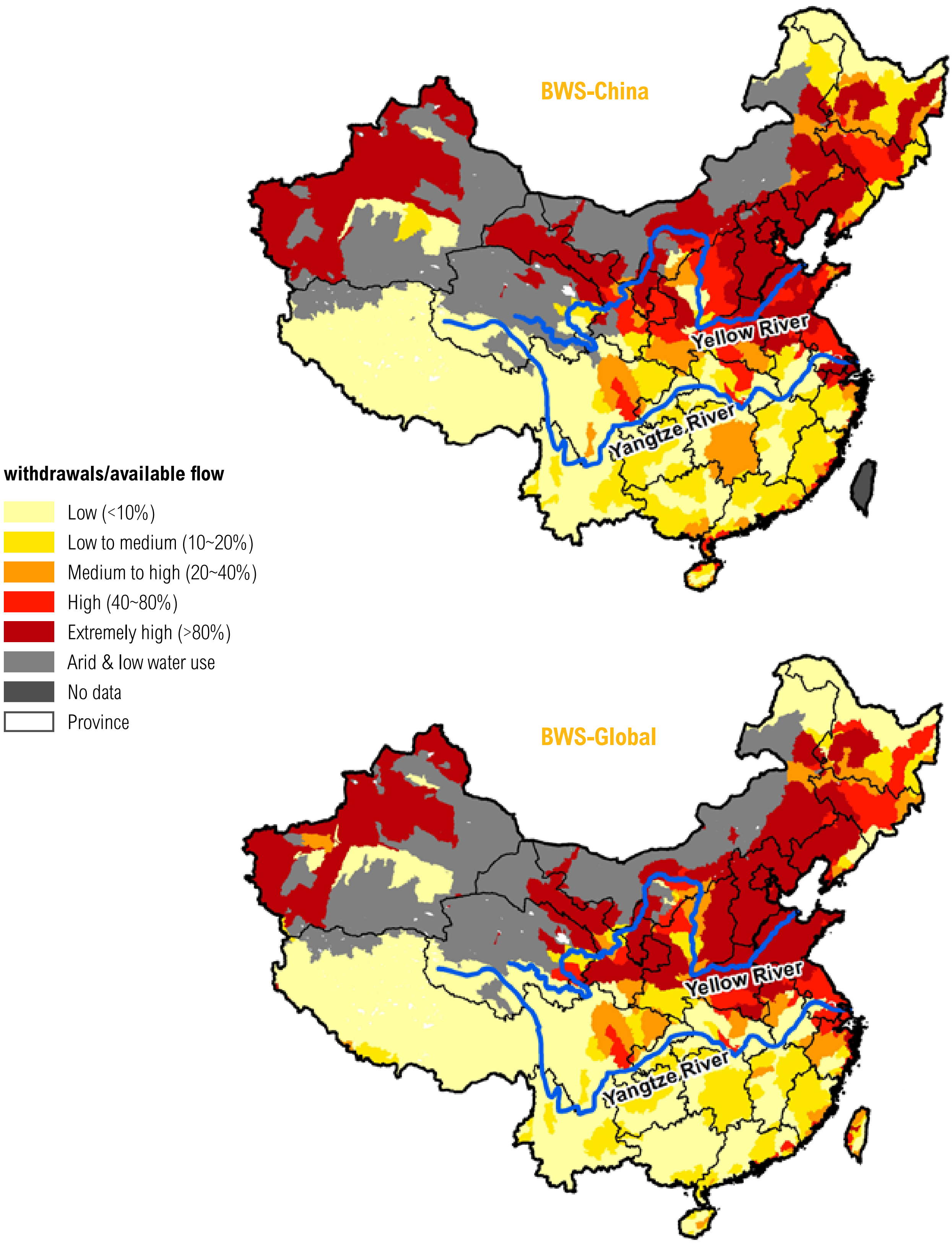
However, a closer look at the catchment level reveals differences. For example, the BWS-China map shows less stress than the BWS-Global map in the downstream areas of the Yellow River. This reflects BWS-Global's overestimation of water withdrawals, particularly in the industrial sector. As noted above, an important difference between BWS-Global and BWS-China is the industrial water withdrawal disaggregation methodology: BWS-Global uses nighttime lights, while BWS-China uses industrial factory locations and their gross output. Compared with nighttime lights, industry factory locations provide more detailed and accurate information on the likely location of industrial water withdrawals. For example, although nighttime lights are used as a proxy for industrial water use, the dataset also captures streets and roads with lights where industrial water withdrawals do not occur. In the downstream areas of the Yellow River, many streets and roads captured in the nighttime lights dataset are allocated to industrial water withdrawals.

In contrast, the BWS-China map shows higher stress than the BWS-Global map in the river mouth areas of the Yangtze River. In this case, BWS-Global significantly underestimated domestic withdrawals. These differences are attributable to the more detailed water withdrawal data and higher resolution spatial datasets used to develop BWS-China. In these areas, the Chinese census indicates a higher population than the estimated population in the Gridded Population of the World dataset. Since this technical note's main focus is on the methodology of developing BWS-China, we do not provide a detailed comparison of the two population datasets. We will compare the BWS-Global map and BWS-China map in more detail in a future publication.

Conclusion

BWS-China can serve as a model for other stakeholders (e.g. governments, businesses, investors, and nongovernmental organizations) wishing to develop baseline water stress assessments using locally relevant datasets in their countries. Users are encouraged to employ BWS-Global for a global understanding of water stress and comparison across countries and larger regions, and to use BWS-China for more detailed, geographically specific information on water stress in China. Investors, companies, government agencies, and others with interest in China can use BWS-China to evaluate investment opportunities, and to enhance their understanding of potential water risks and begin to address them.

Figure 9 | **BWS-China and BWS-Global Comparison (2010)**



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ENDNOTE

1. For detailed descriptions and calculations of Aqueduct's global baseline water stress indicator, see http://www.wri.org/sites/default/files/Aqueduct_Global_Maps_2.1-Constructing_Decicion-Relevant_Global_Water_Risk_Indicators_final_0.pdf

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The authors alone are responsible for the content of this technical note, and any omissions, inaccuracies, or errors are our own.

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ABOUT THE MAPS

The boundaries, colors, and other information shown on these maps do not imply on the part of the WRI any judgment on the legal status of any territory or the endorsement or acceptance of such boundaries.

ABOUT WRI

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

Our Challenge

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

Our Vision

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

Our Approach

COUNT IT

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

CHANGE IT

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

SCALE IT

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

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Ministry of Foreign Affairs of the Netherlands

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