Role of External Water Footprint in Influencing China’s Water Stress

Junguo Liu

Beijing Forestry University

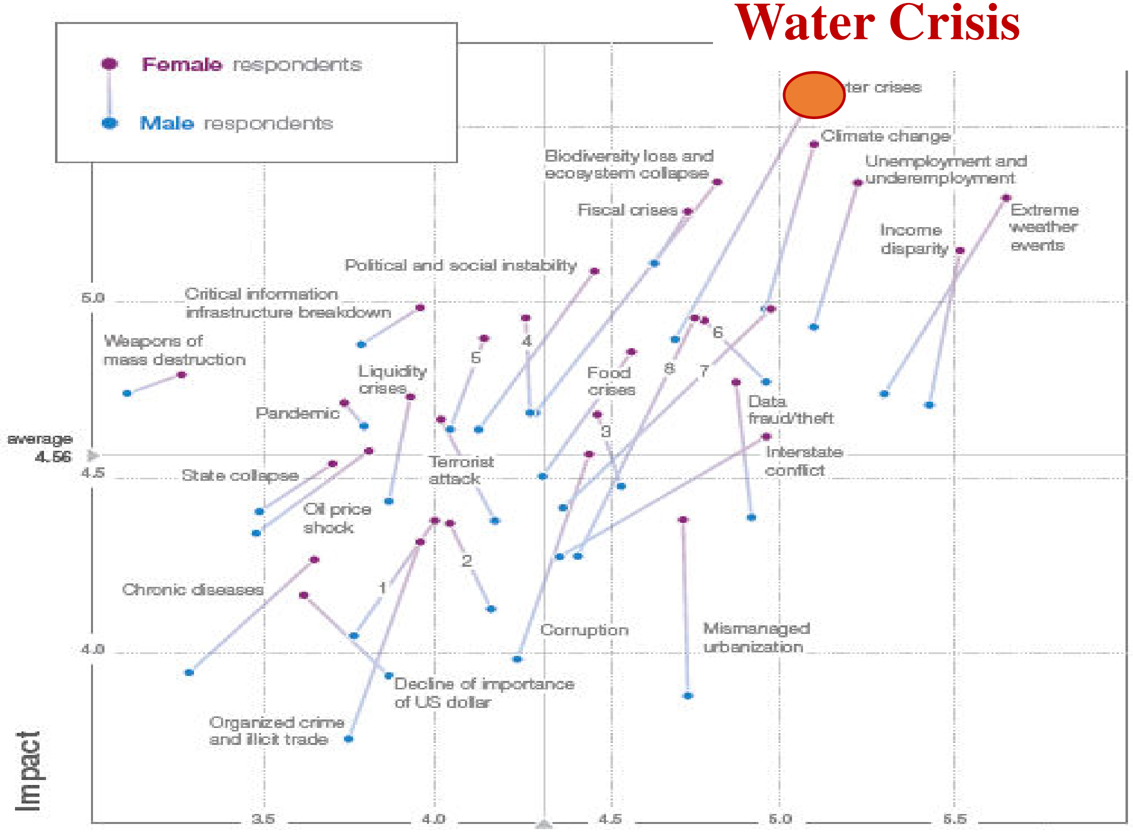
XVth IWRA World Water Congress

Edinburgh, 25-29 May 2015

According to the “Global Risks 2014” of the World Economic Forum Report, water crisis and extreme weather events have been identified as two of the top 10 global risks.

Water Crisis

Impact on World Economy

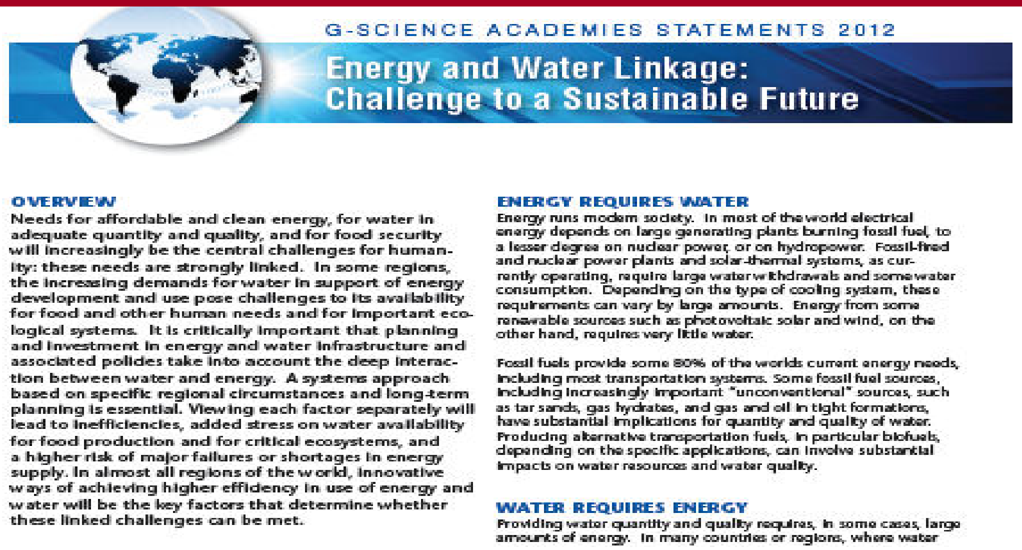


Likelihood

Global Risks Landscape 2014

- One third world people already lives in a country with moderate to high water stress
- By 2030 nearly half the global population could be facing water scarcity

G-science Academies Statement



G-SCIENCE ACADEMIES STATEMENTS 2012

Energy and Water Linkage: Challenge to a Sustainable Future

OVERVIEW

Needs for affordable and clean energy, for water in adequate quantity and quality, and for food security will increasingly be the central challenges for humanity: these needs are strongly linked. In some regions, the increasing demands for water in support of energy development and use pose challenges to its availability for food and other human needs and for important ecological systems. It is critically important that planning and investment in energy and water infrastructure and associated policies take into account the deep interaction between water and energy. A systems approach based on specific regional circumstances and long-term planning is essential. Viewing each factor separately will lead to inefficiencies, added stress on water availability for food production and for critical ecosystems, and a higher risk of major failures or shortages in energy supply. In almost all regions of the world, innovative ways of achieving higher efficiency in use of energy and water will be the key factors that determine whether these linked challenges can be met.

ENERGY REQUIRES WATER

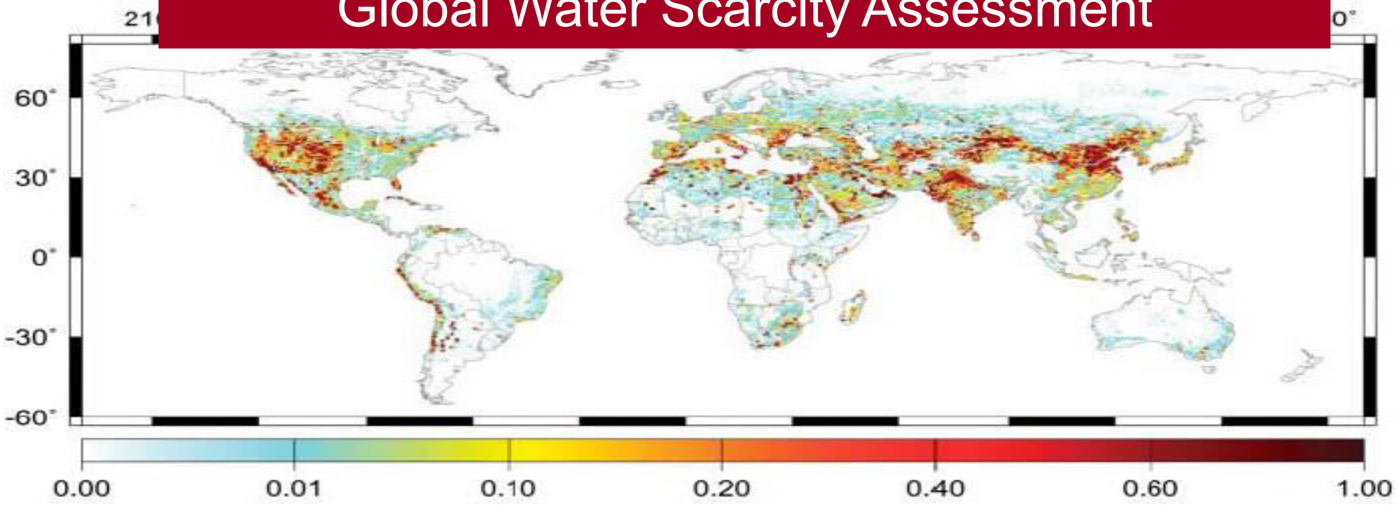
Energy runs modern society. In most of the world electrical energy depends on large generating plants burning fossil fuel, to a lesser degree on nuclear power, or on hydropower. Fossil-fired and nuclear power plants and solar-thermal systems, as currently operating, require large water withdrawals and some water consumption. Depending on the type of cooling system, these requirements can vary by large amounts. Energy from some renewable sources such as photovoltaic solar and wind, on the other hand, requires very little water.

Fossil fuels provide some 80% of the worlds current energy needs, including most transportation systems. Some fossil fuel sources, including increasingly important "unconventional" sources, such as tar sands, gas hydrates, and gas and oil in tight formations, have substantial implications for quantity and quality of water. Producing alternative transportation fuels, in particular biofuels, depending on the specific applications, can involve substantial impacts on water resources and water quality.

WATER REQUIRES ENERGY

Providing water quantity and quality requires, in some cases, large amounts of energy. In many countries or regions, where water

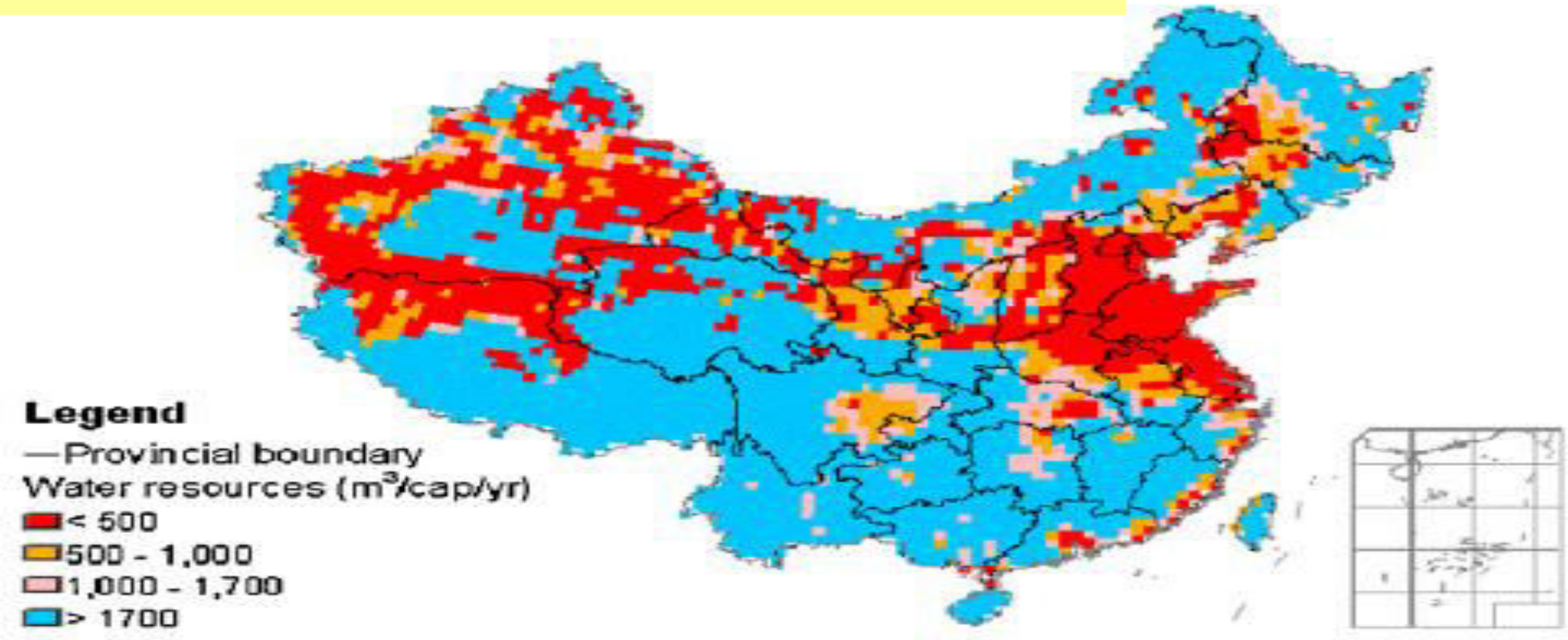
Global Water Scarcity Assessment



Oki and Kanae, 2006. *Science;* Vörösmarty et al., 2000. *Science;* Vörösmarty et al., 2010. *Nature*

According to the *G-science Academies Statement* for the G8 Summit in 2012, "How to meet human's water and energy demand" is one of the three largest global challenges

Water scarcity is a great challenge in China

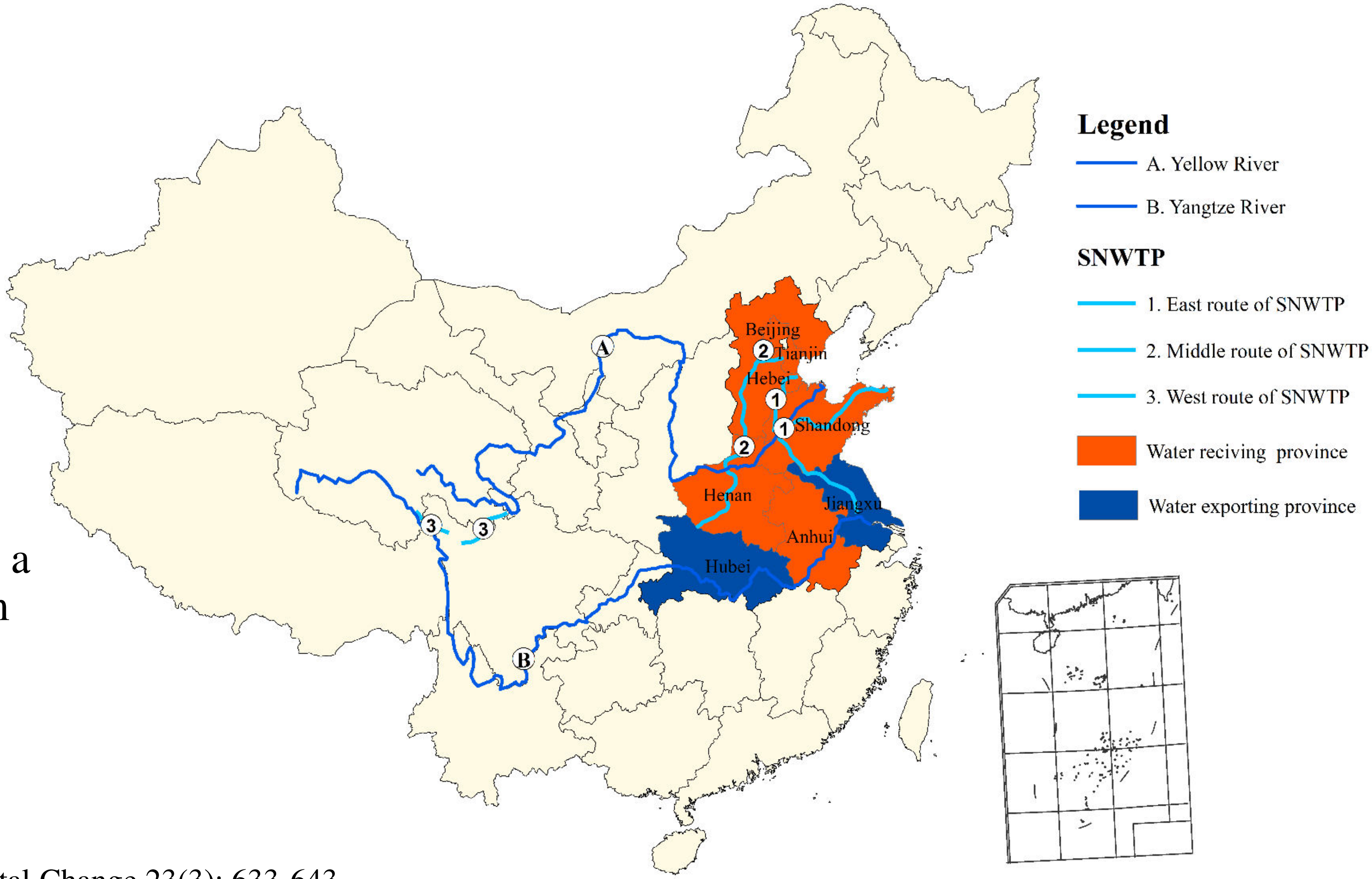


Liu et al., 2013. Global Environmental Change

- Per capita water resources: 2200 m^3
- Per capita water resources in northern China: 757 m3
- Huang-Huai-Hai River Basins (accurate water scarcity)
  - 1/3 of China's population
  - 35% of industrial output
  - 40% of cultivated land and 50% of national grain production
  - but only 7.2% of the nation's water resources (462 m^3/cap/yr)

Background

China has been developing over twenty major physical water transfer projects with a total length of over 7200km (Liu et al., 2013).



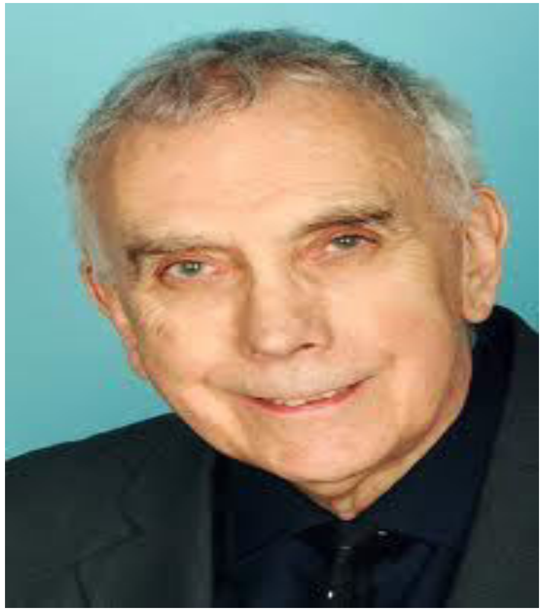
Liu et al., 2013. Global Environmental Change 23(3): 633-643.

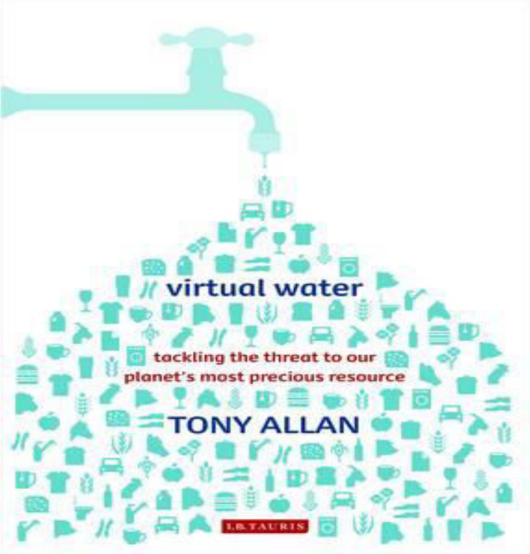
Zhao, Liu* et al., 2015. PNAS 112 (4): 1031-1035

The South-North Water Transfer Project (SNWTP) – The world's largest physical water transfer project.

- **A large amount of water transferred from water-rich region to water-poor region**
- **The project connects four major rivers in China (Yangtze river with the Huang, Huai and Hai Rivers), and affects one-third of China’s landmass**

Virtual water





Water scarce regions import water-intensive foods to alleviate their water scarcity. This trade is termed as "virtual water trade". Since this water flow is invisible, virtual water is also called "**ultraviolet** water"

Each year, more water is now imported into the Middle East and North Africa in virtual form than physically flows into Egypt via the Nile

Background

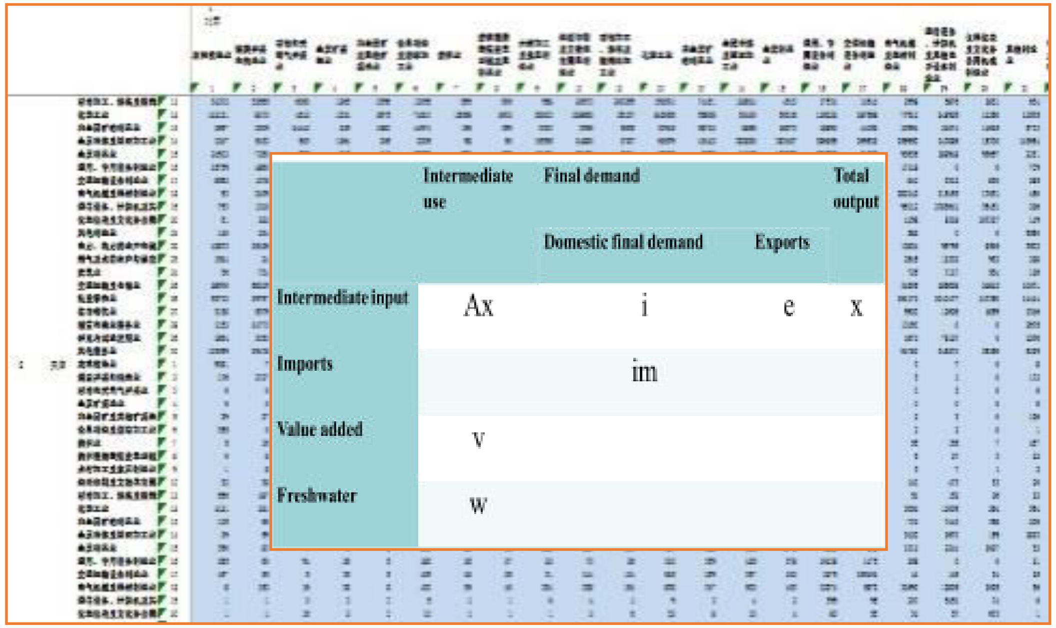
An important question is if the water redistributions through virtual and physical forms can be effective in **mitigating regional water stress** in China.

To answer this question:

We report on our quantification of China's physical and virtual water flows at the provincial level for the year 2007, and a scenario analysis in 2030.

Data

A Multi-region input-output (MRIO) table was aggregated to 30 industrial sectors within 30 Chinese provinces.



The volumes of physical water transfer and water use data for agriculture and service sectors for each province was acquired from the **Water Resources Bulletin**

The industrial water use data with detailed sectors was taken from the **Chinese Economic Yearbook 2008**

Methodology

A 'Water embodied in Trade' (WET) approach to account for water impact of trade 'Water embodied in Trade' (WET).

The WET method assumes that bilateral trade between regions to intermediate and final consumption will be combined and reallocated to final consumption

$$x_r = A_{rr}x_r + y_{rr} + \sum_{s\neq r} e_{rs}$$

$$x_r = (I-A_{rr})^{-1}(y_{rr} + \sum_{s\neq r} e_{rs})$$

$$d_r = {}^{w_r}\!/_{x_r}$$

$$t_r = d_r(I-A_r)^{-1}$$

$$w_r = d_r(I-A_{rr})^{-1}(y_{rr} + \sum_{s\neq r} e_{rs}) = t_r(y_{rr} + \sum_{s\neq r} e_{rs})$$

$$w_r = d_r(I-A_{rr})^{-1}(y_{rr} + \sum_{s\neq r} e_{rs}) = t_r(y_{rr} + \sum_{s\neq r} e_{rs})$$

$$vwe_{rs} = d_r(I-A_{rr})^{-1}\sum_{s\neq r} e_{rs}$$

$$vwi_{rs} = d_1(I-A_{11})^{-1}e_{1r} + d_2(I-A_{22})^{-1}e_{2r} + \cdots + d_s(I-A_{ss})^{-1}e_{sr}$$

$$\begin{bmatrix} x_1 \\ \vdots \\ x_r \\ \vdots \\ x_p \end{bmatrix} = \begin{bmatrix} A_{11} & \cdots & 0 & \cdots & 0 \\ \vdots & \ddots & \vdots & & \vdots \\ 0 & \cdots & A_{rr} & \cdots & 0 \\ \vdots & & \vdots & \ddots & \vdots \\ 0 & \cdots & 0 & \cdots & A_{pp} \end{bmatrix} \begin{bmatrix} x_1 \\ \vdots \\ x_r \\ \vdots \\ x_p \end{bmatrix} + \begin{bmatrix} y_1 + \sum y_{1r} \\ \vdots \\ y_r + \sum y_{rr} \\ \vdots \\ y_p + \sum y_{pr} \end{bmatrix}$$

Methodology

The water stress index considering physical and virtual water flows

$$WSI^* = \frac{WU_c}{Q} = \frac{WU + VW_{net,im}}{Q} = \frac{WW + PW_{net,im} + VW_{net,im}}{Q}$$

$$WSI = \frac{WW}{Q} = \frac{WU - PW_{net,im}}{Q}$$

$$WSI^* - WSI = \frac{PW_{net,im} + VW_{net,im}}{Q}$$

Levels of water stress	Water stress index
Extreme	>1
Severe	0.4 -1
Moderate	0.2-0.4
No stress	<0.2

WSI refers to water stress arising from water withdrawal from available local water sources

WSI* represents the water stress indicator that calculates the hypothetical water stress on the local hydro-ecosystem if the importing region would not have physical and virtual inflows available and would withdraw the required water entirely from local sources.

Results

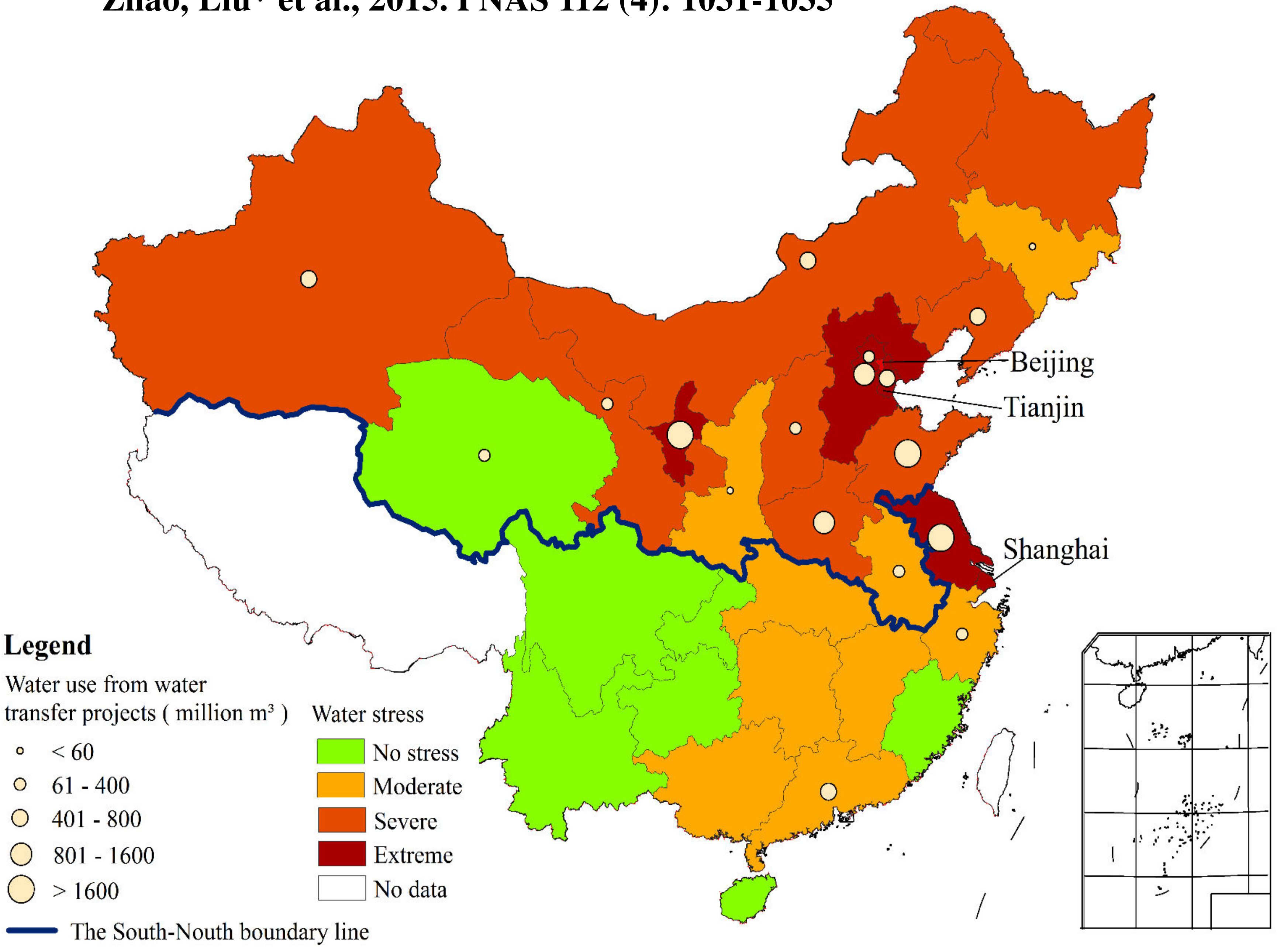
Zhao, Liu* et al., 2015. PNAS 112 (4): 1031-1035

Water stress index

23 of the 30 Chinese provinces had at least moderate water stress (WSI>0.2)

Physical water flows

In 2007, physical water flows by water transfer projects amounted to 26.3 Gm^3, accounting for 4.5% of national water supply and occurring in 18 provinces in China.

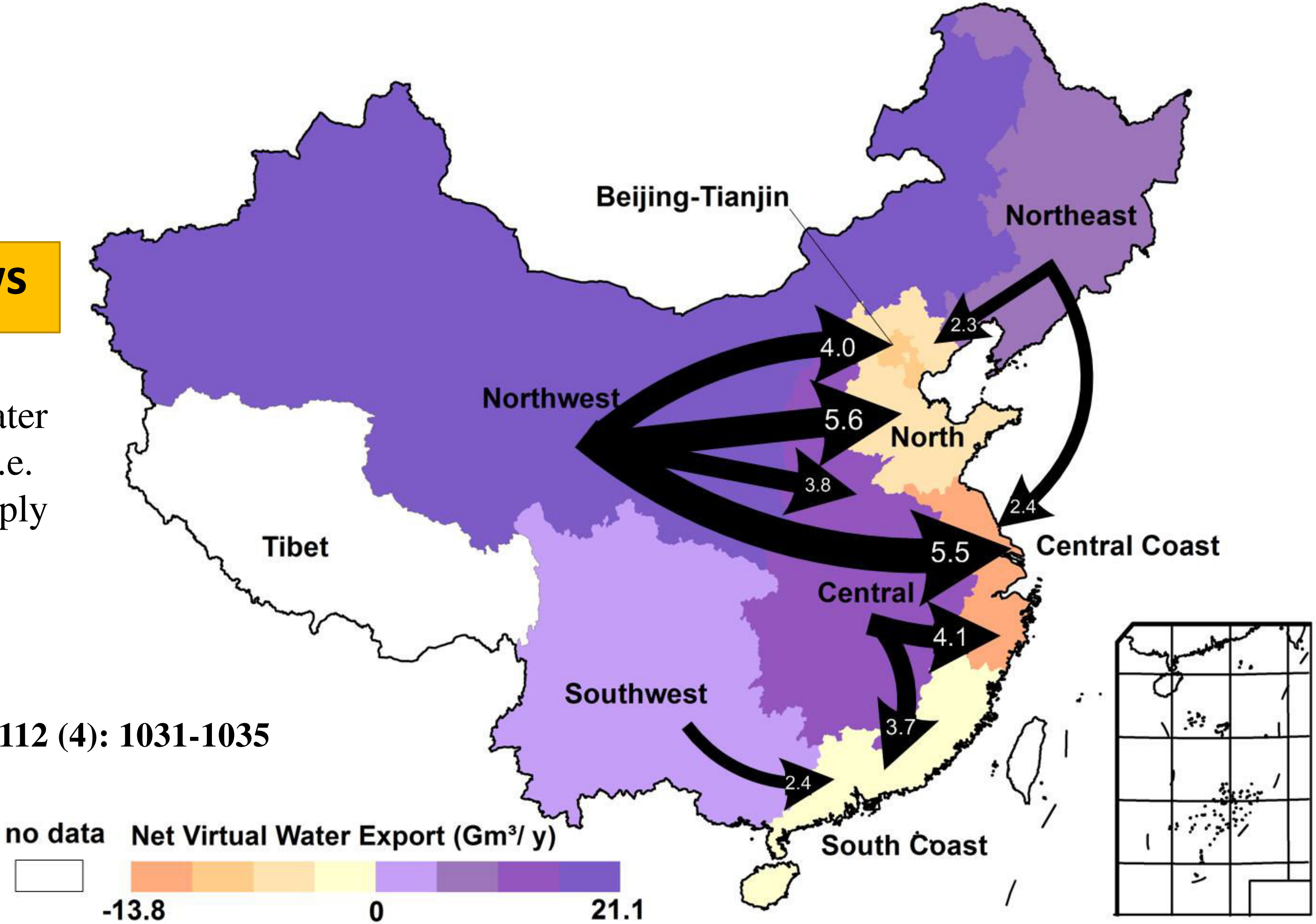


Results

Virtual water flows

The total volume of virtual water flows was 201 Gm^3 in 2007, i.e. 35% of the national water supply was used for inter-provincial virtual water trade.

Zhao, Liu* et al., 2015. PNAS 112 (4): 1031-1035

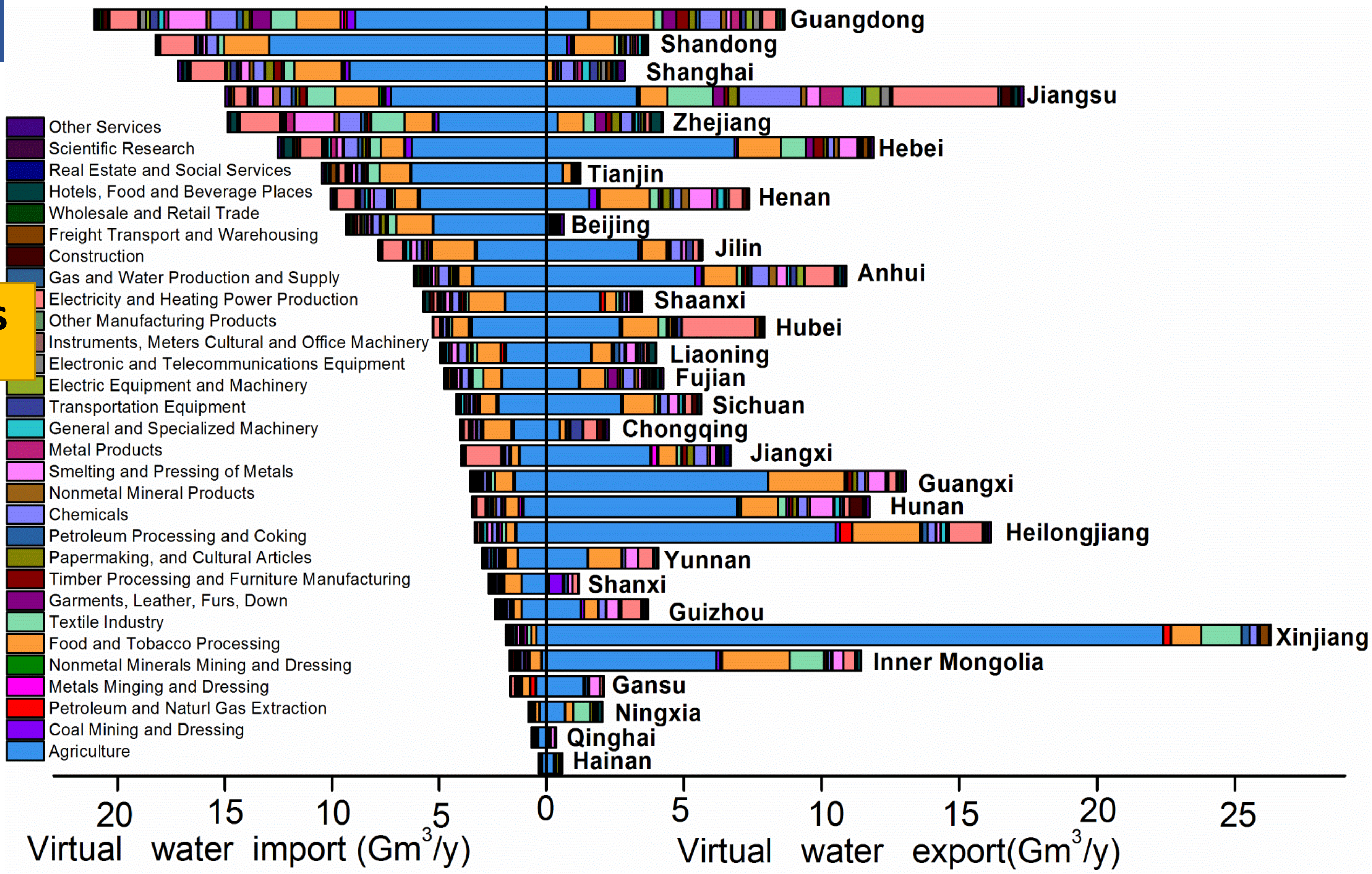


Virtual water flows among eight economic regions

Results

Virtual water flows

Agriculture has the greatest share of virtual water trade accounting for 48% of virtual water export .



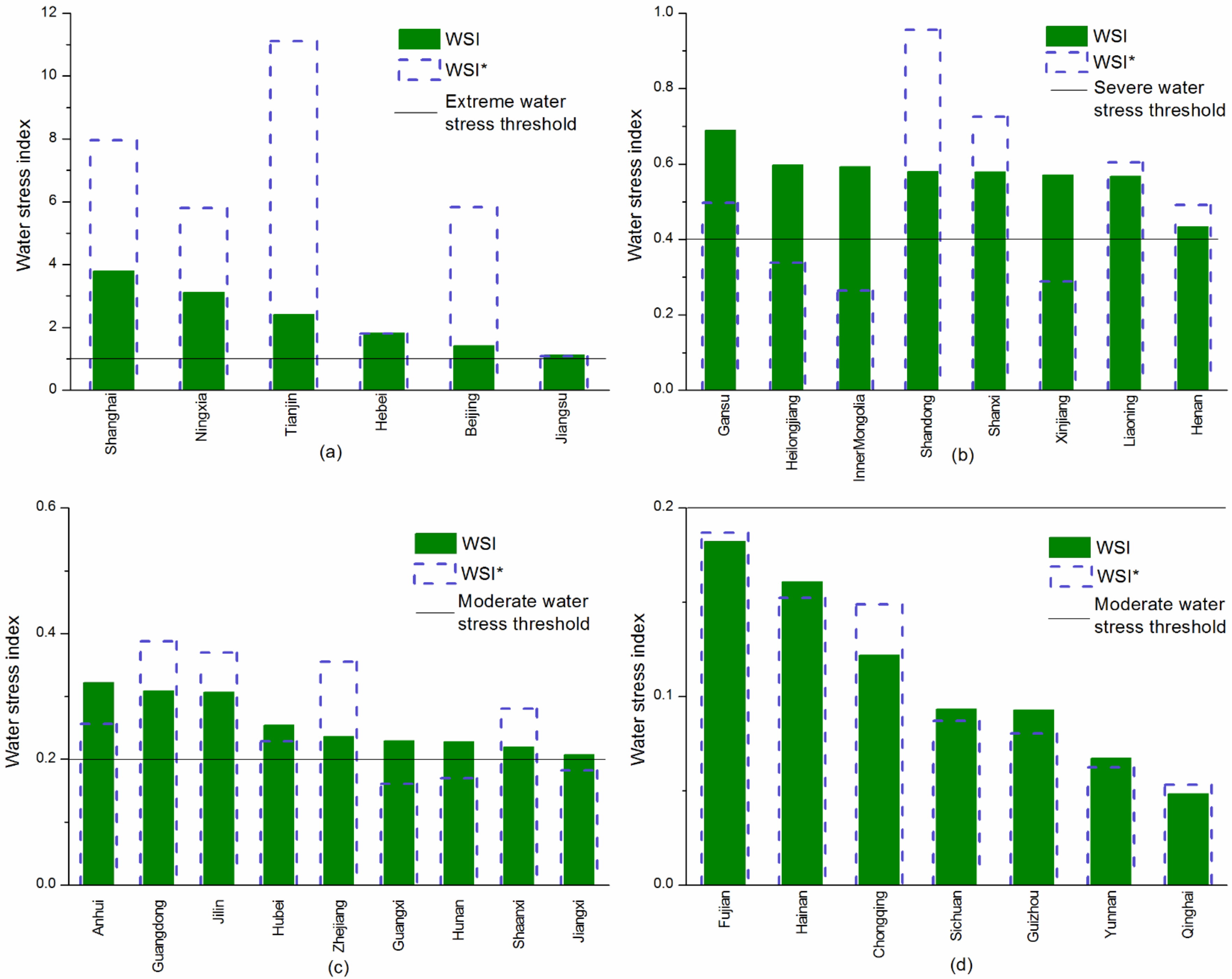
Zhao, Liu* et al., 2015. PNAS 112 (4): 1031-1035

Results

12 water stressed provinces benefited from net virtual and physical water imports ($WSI^* > WSI$).

11 already water stressed provinces the situation was further compounded through net virtual and physical water exports ($WSI^* < WSI$)

Zhao, Liu* et al., 2015. PNAS 112 (4): 1031-1035



Discussion

Unsustainable water transfer

- In 2007 and 2030, several economically developed provinces have(would) relied(rely) on large amounts of physical and virtual water to help ameliorate their water stress – Beijing, Tianjin, Shandong, Shanghai, Zhejiang, and Guangdong

- Meanwhile, both virtual and physical water transfers were shown to have (would) exacerbated (exacerbate) water stress for several top water exporting provinces in 2007 and 2030 - Xinjiang, Heilongjiang, and Inner-Mongolia

To prevent such a situation, more emphasis should be placed on water demand management rather than solely relying upon supply-orientated management

Zhao, Liu* et al., 2015. PNAS 112 (4): 1031-1035

Discussion

Mitigating water stress through efficiency improvement

Agricultural irrigation efficiency

- Agricultural irrigation efficiency for the entire country will increase by 23% -from 0.48 in 2007 to 0.59 in 2030 (reference scenario).
- At provincial level the efficiency gains range between 11%-59%
- Such efficiency gains will help reduce irrigation water demand by 26% (122 Gm3)

Industrial water intensity

- The industrial water intensity of the whole country is required to decrease by 81% - from 2.54 m3/thousand CNY in 2007 to 0.48 m3/thousand CNY in 2030 (reference scenario).
- The efficiency gains in industry would help to reduce 80% of industrial water demand (949 Gm3).

Zhao, Liu* et al., 2015. PNAS 112 (4): 1031-1035

- A working group on water scarcity assessment was established under IAHS-Panta Rhei
- WG is chaired by Junguo Liu, and consists of 16 experts from 9 countries
- Members include Prof. Hubert Savenije (IAHS president, AGU Union Fellow), Taikan Oki (Coordinating lead authors for IPCC report, AGU Union Fellow), Arjen Hoekstra (father of "water footprint")

- This WG will focus on the improvement of water scarcity assessment by explicitly considering water quantity and quality as well as environmental flow requirements.
- Future scenarios will be established taking into account the continuous shifts of consumption pattern, socioeconomic development, increasing water pollution, and climate change.

A Spring School on Global Climate Change Impacts Assessment and Water Resources during May 15-22 in Beijing

Submitted by alberto on Sat, 05/09/2015 - 10:56

A Spring School on Global Climate Change Impacts Assessment and Water Resources will be organized during May 15-22 in Beijing. It is funded by my university (Beijing Forestry University) and the National Natural Science Foundation of China, as one key events of the Panta Rhei working group "Water Scarcity Assessment". The School is organized by prof. Junguo Liu, Beijing Forestry University, Beijing, China and Director-general of the Society for Ecological Restoration in Beijing, China. The programme is available here.

NEW

Alberto Montanari
Panta Rhei Chair 2013-15

Read more

The reports of the activity of the Panta Rhei Working Groups in 2014

Submitted by alberto on Sat, 04/18/2015 - 00:23

The reports of the activity carried out by the Panta Rhei Working Groups in 2014 is available for download here below. The WGs have carried out an amazing activity last year, therefore proving the enthusiasm of the Panta Rhei researchers and the popularity and significance of the Panta Rhei themes.

I would like to thank very much the WG Leaders and all the researchers that are working in Panta Rhei. We are

Take home messages

- **Integration of water and economic models** provides in-depth insights into water resources assessment
- Both physical and virtual water transfers **exacerbate water stress for the water exporting regions**
- **Improving water use efficiency** is key to mitigating water stress, but the efficiency gains will be largely offset by the water demand increase caused by continued economic development.
- Much greater attention needs to be paid to **water demand management** rather than the current focus on supply-oriented management.

Physical and virtual water transfers for regional water stress alleviation in China

Xu Zhao[a], Junguo Liu[a,1], Qingying Liu[a], Martin R. Tillotson[b], Dabo Guan[c], and Klaus Hubacek[d]

[a]School of Nature Conservation, Beijing Forestry University, Beijing 100083, China; [b]water@leeds, School of Civil Engineering, University of Leeds, Leeds LS2 9JT, United Kingdom; [c]Water Security Research Centre, School of International Development, University of East Anglia, Norwich NR4 7TJ, United Kingdom; and [d]Department of Geographical Sciences, University of Maryland, College Park, MD 20742

Edited by Peter H. Gleick, Pacific Institute for Studies in Development, Environment, and Security, Oakland, CA, and approved December 19, 2014 (received for review March 4, 2014)

Water can be redistributed through, in physical terms, water transfer projects and virtually, embodied water for the production of traded products. Here, we explore whether such water redistributions can help mitigate water stress in China. This study, for the first time to our knowledge, both compiles a full inventory for physical water transfers at a provincial level and maps virtual water flows between Chinese provinces in 2007 and 2030. Our results show that, at the national level, physical water flows because of the major water transfer projects amounted to 4.5% of national water supply, whereas virtual water flows accounted for 35% (varies

the SNWTP has proved highly controversial in its potential impacts on both exporting and importing river ecosystems and its huge capital cost (~$60 US billion), scholars have suggested that the North China Plain should, instead, reduce the export of water-intensive products or even import virtual water from southern China (11, 13, 15–17). An important question is if such redistributions can be effective in mitigating regional water stress in China.

To answer this question, we report here on our quantification of China's physical and virtual water flows at the provincial level for the year 2007. We have used the most recent interregional

(1) Zhao X., **Liu J.***, Liu Q., Tillotson M.R., Guan D., Hubacek K., 2015. Physical and virtual water transfers for regional water stress alleviation in China. *Proceedings of the National Academy of Sciences of the United States of America*. 112(4): 1031-1035.

(2) **Liu J.***, Zang C., Tian S., Liu J., Yang H., Jia S., You L., Liu B., Zhang M., 2013. Water conservancy projects in China: achievements, challenges and way forward. Global Environmental Change 23(3): 633-643.

Thank you for your attention

water21water@yahoo.com