Homeland Defense & Security Information Analysis Center

HDIAC *Critical Infrastructure Protection* Webinar:

A detailed global map of the hydro-economy: water footprints, teleconnections and indirect security risks of drought

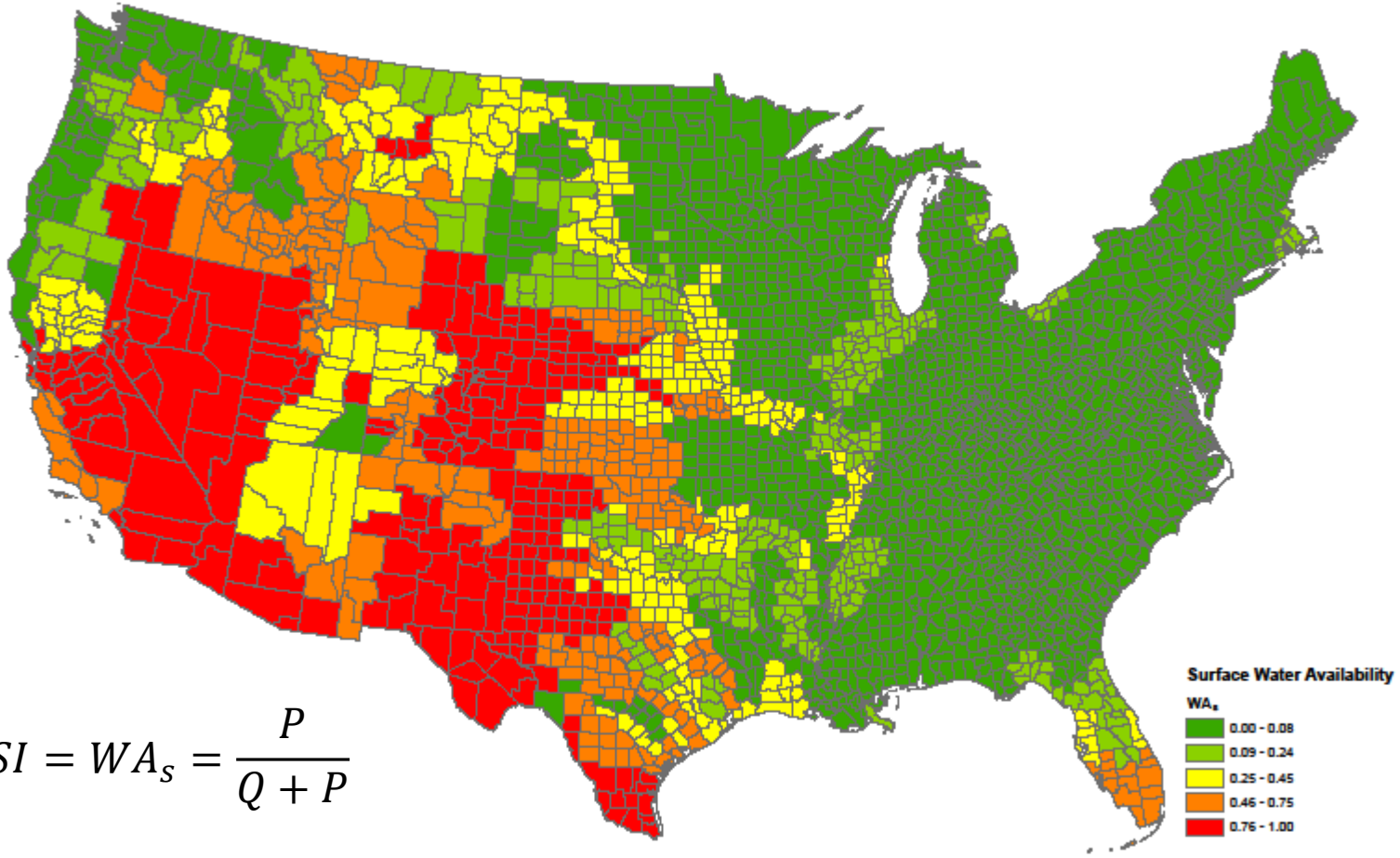
December 10, 2015

Benjamin L. Ruddell
Ph.D., P.E., Associate Professor
Arizona State University

Homeland Defense & Security Information Analysis Center (HDIAC)
(865) 535-0088
www.hdiac.org

Department of Defense Information Analysis Centers

Water Scarcity and Drought is a Challenge for Water Security, Vulnerability, and Resilience

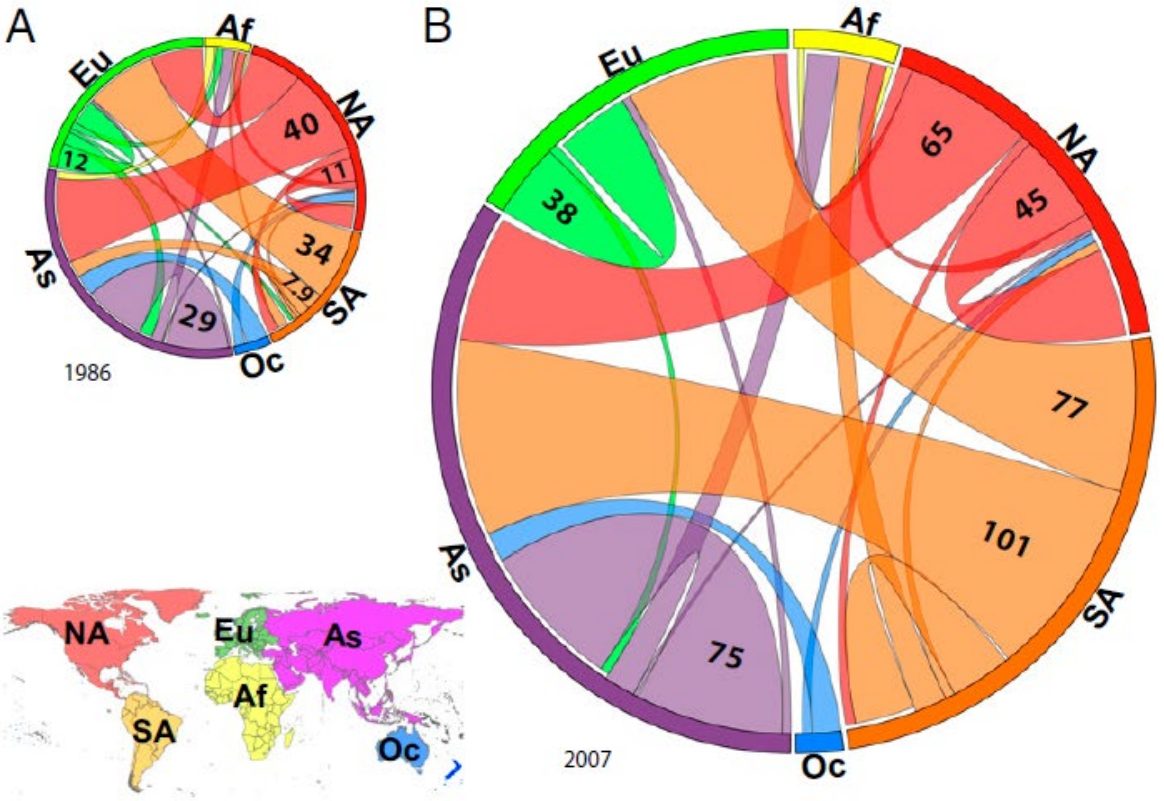


$$WSI = WA_s = \frac{P}{Q + P}$$

V. C. Tidwell, P. H. Kobos, L. A. Malczynski, G. Klise, C. R. Castillo, Exploring the water-thermoelectric power Nexus. *Journal of Water Resources Planning and Management* **138**, 491-501 (2012).

Drought Teleconnections: A Major 21st Century Vulnerability

- Global and regional trade have grown dramatically since the 1980s
- Trade creates a “teleconnection” and dependency between two locations
- Water teleconnections can be measured with “Virtual Water”
- A virtual water teleconnection implies vulnerability to drought

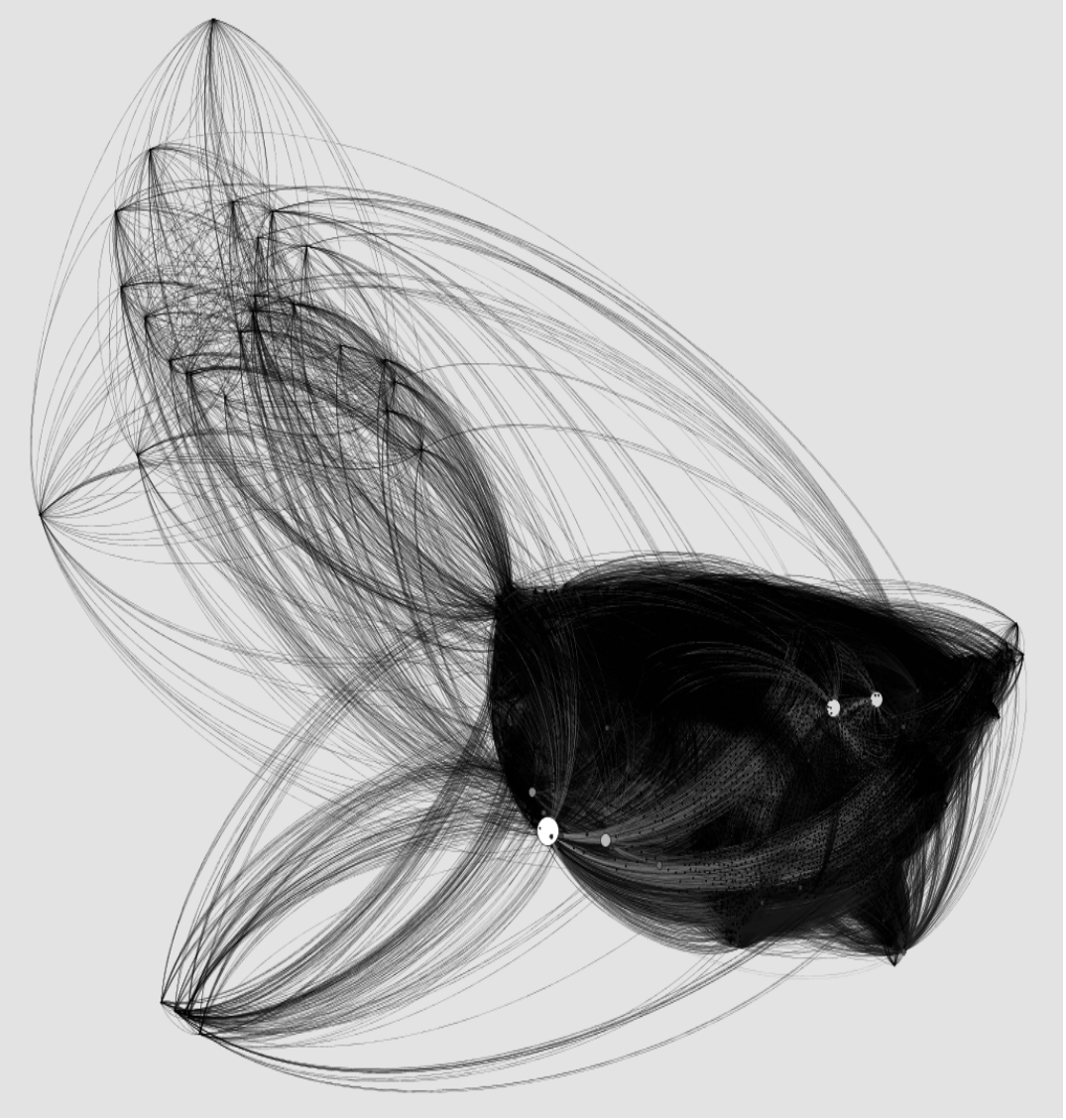


Dalin, C., M. Konar, N. Hanasaki, A. Rinaldo, and I. Rodriguez-Iurbe (2012), Evolution of the global virtual water trade network, PNAS, V.109, No.21, 8353, doi/10.1073/pnas.1203176109

The U.S. National Water-Economy Project (NWEP) has mapped U.S. water teleconnections

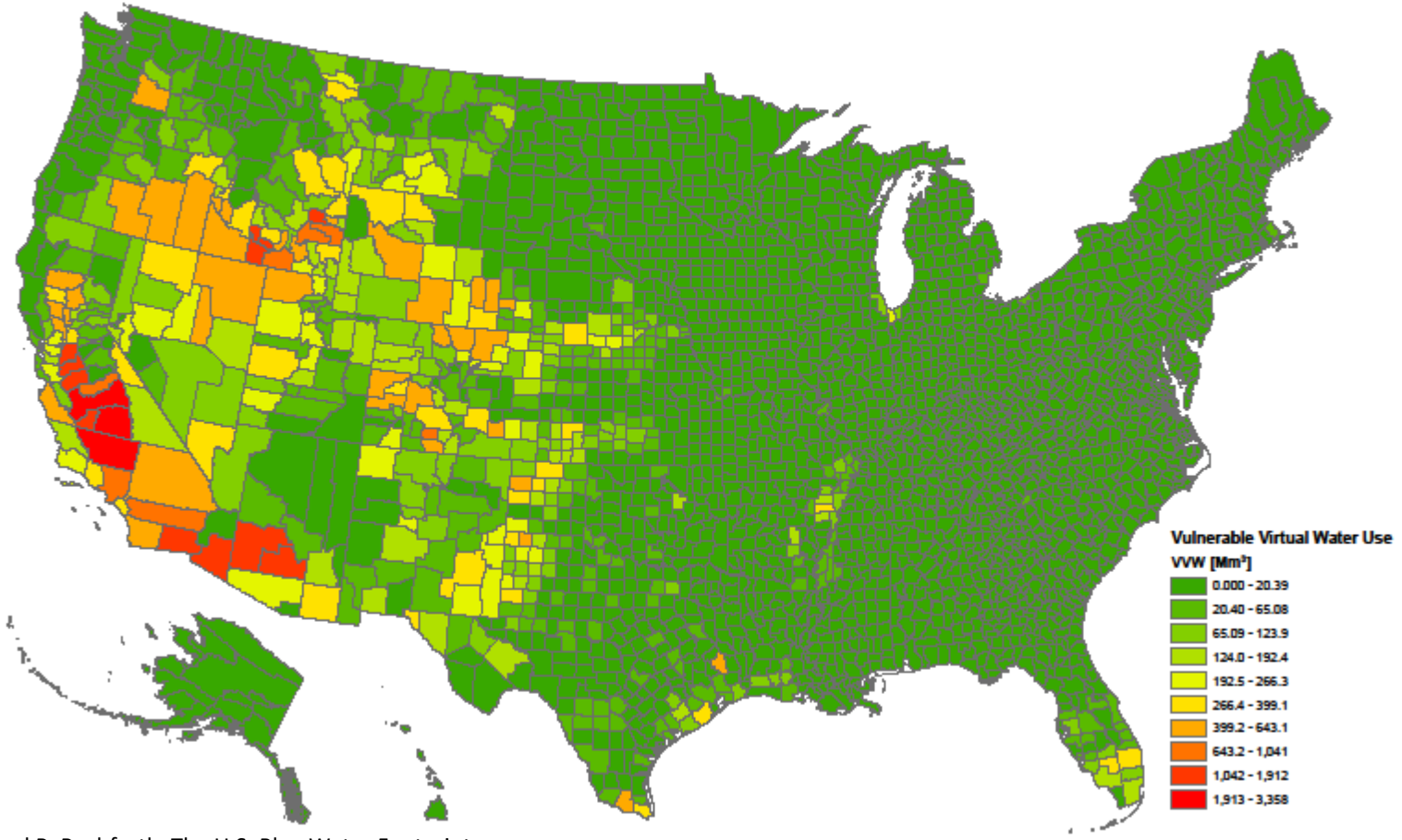
HDIAC
Homeland Defense & Security Information Analysis Center

NWEP
NATIONAL WATER ECONOMY PROJECT



Where are the sources of U.S. Vulnerability to Drought?

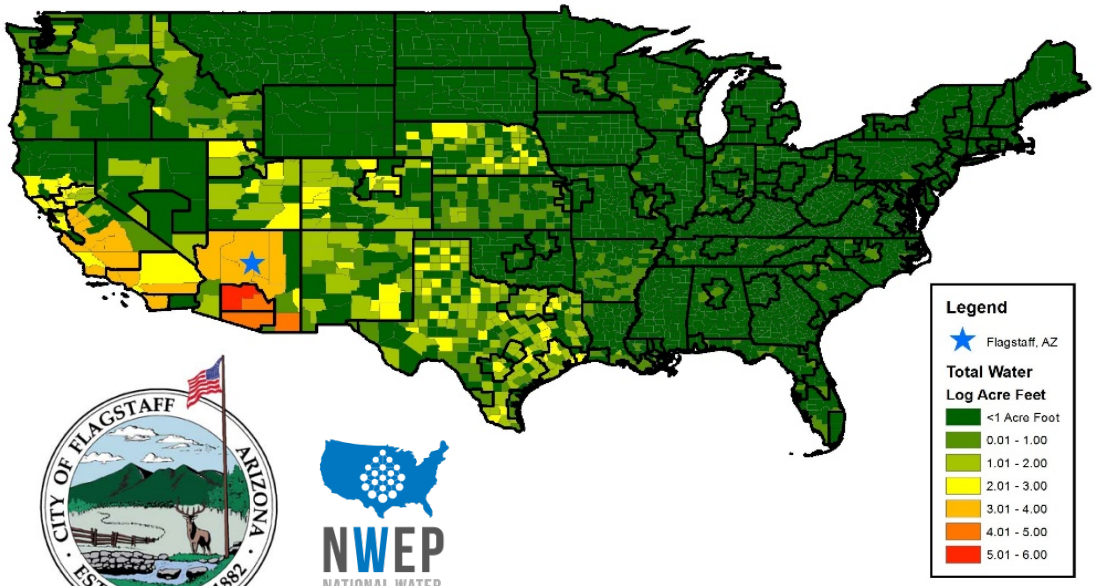
- If drought impacts these locations, the U.S. economy and water supply chain are at risk due to virtual water teleconnections
- This allows us to anticipate the impacts of drought by location

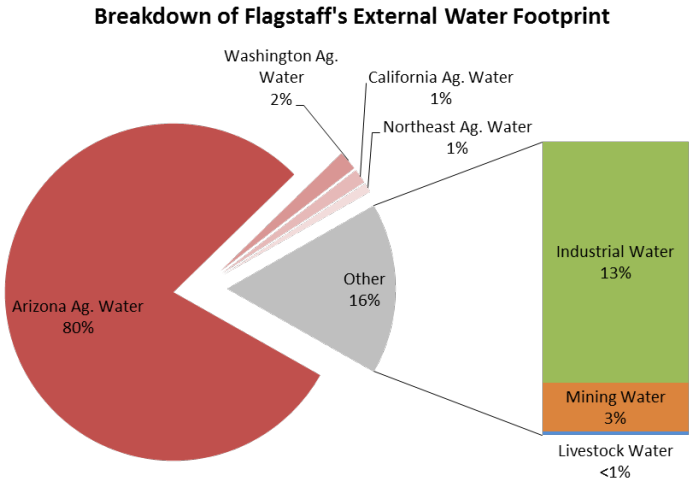


Ruddell, B.L. and R. Rushforth, The U.S. Blue Water Footprint and its Vulnerability to Drought, in review (2016)

Virtual Water Teleconnections of a U.S. City: Flagstaff, Arizona

- It is now understood that drought is a security risk, e.g. Somalia, Syria
- Via trade and infrastructure, there is an indirect vulnerability to drought
- We now have the ability to map the indirect vulnerabilities to drought
- Most of these vulnerable teleconnections are regional, not global
- Lesson: Cities must manage regional drought vulnerabilities

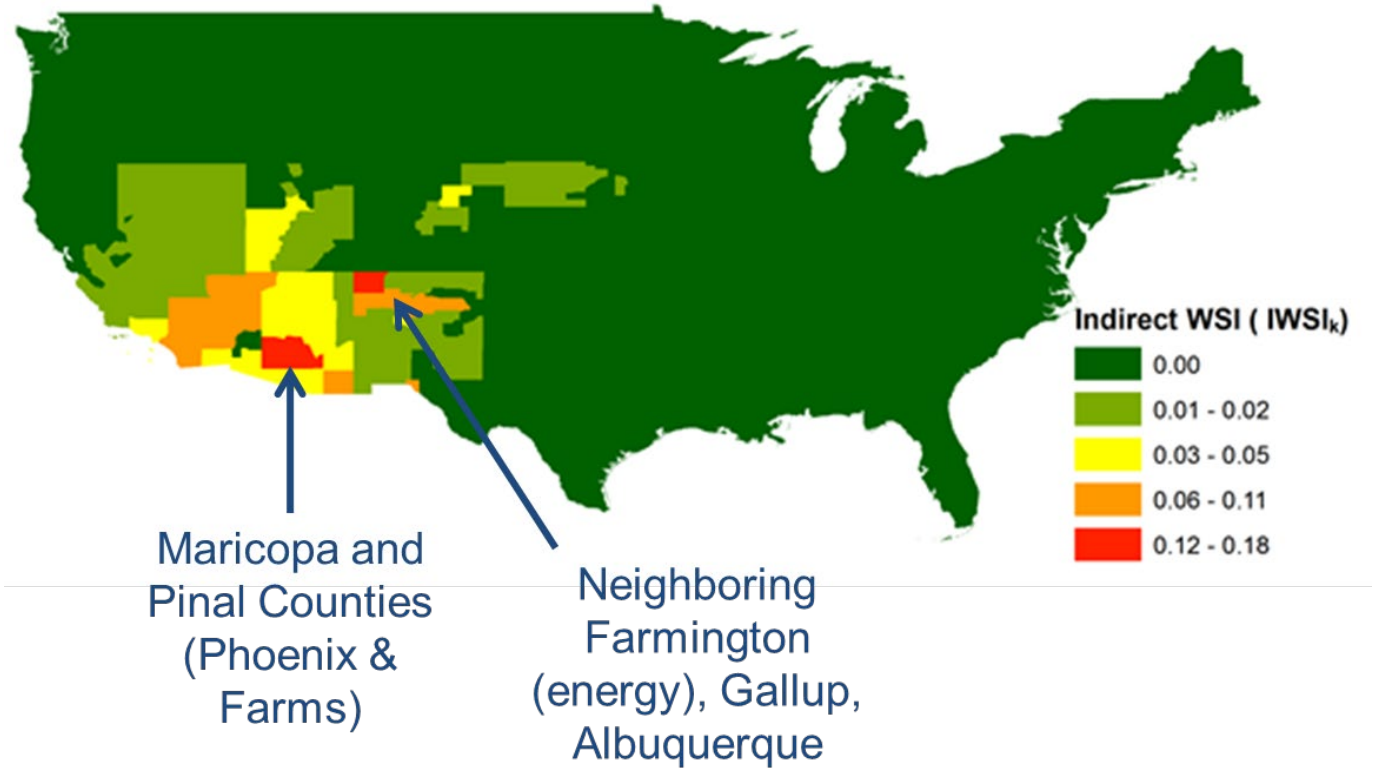




Rushforth, R., and B.L. Ruddell, Urban Water Footprints and Water Sustainability; the water connectivity of Flagstaff, Arizona, Water Resources Research, in review

Flagstaff's Vulnerability to Drought via Virtual Water Teleconnections

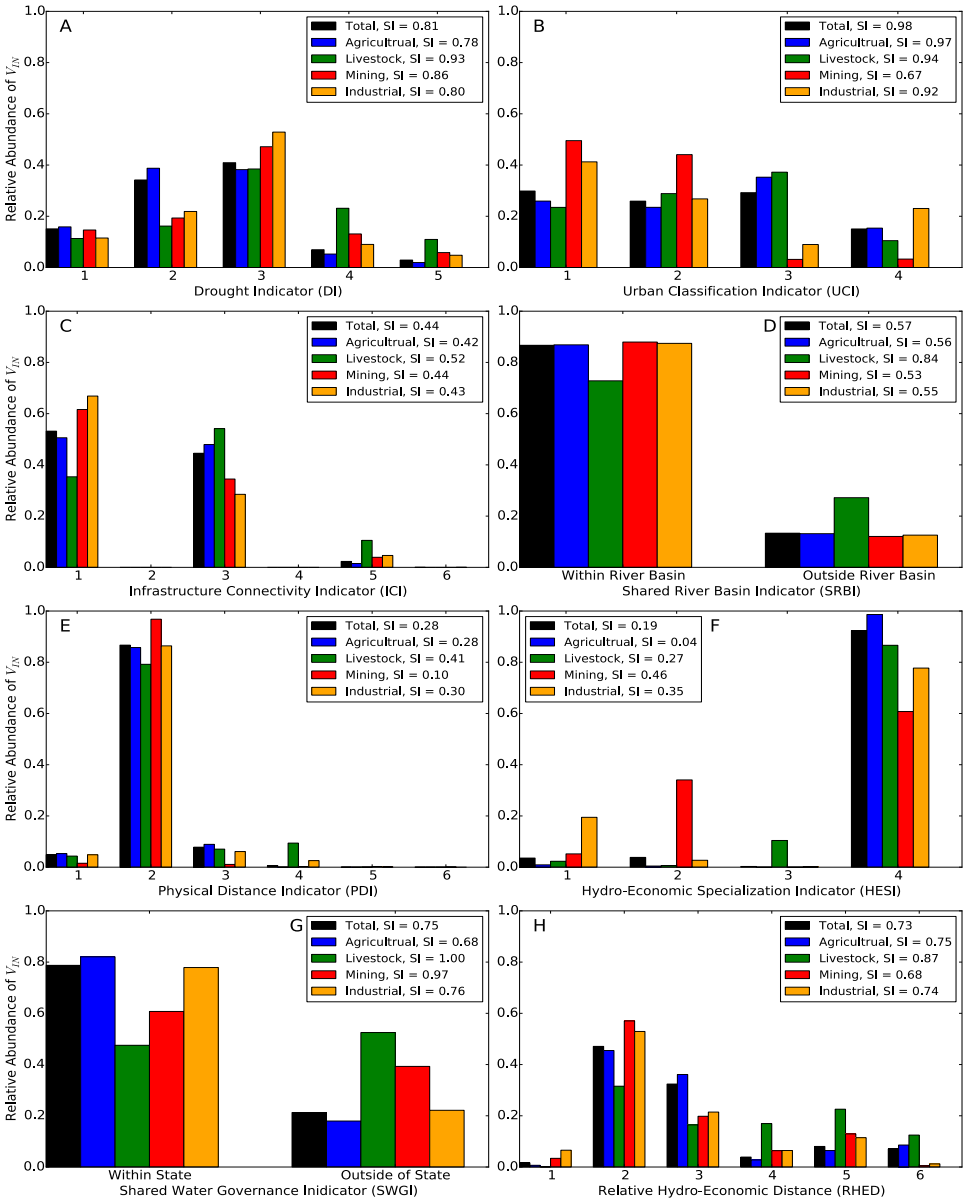
- Flagstaff's vulnerability is concentrated in the Lower Colorado River Basin
- Flagstaff should invest in water security there
- Flagstaff should diversify its water supply chain to other areas
- We can see that Flagstaff will be hit by water shortages in "red" counties



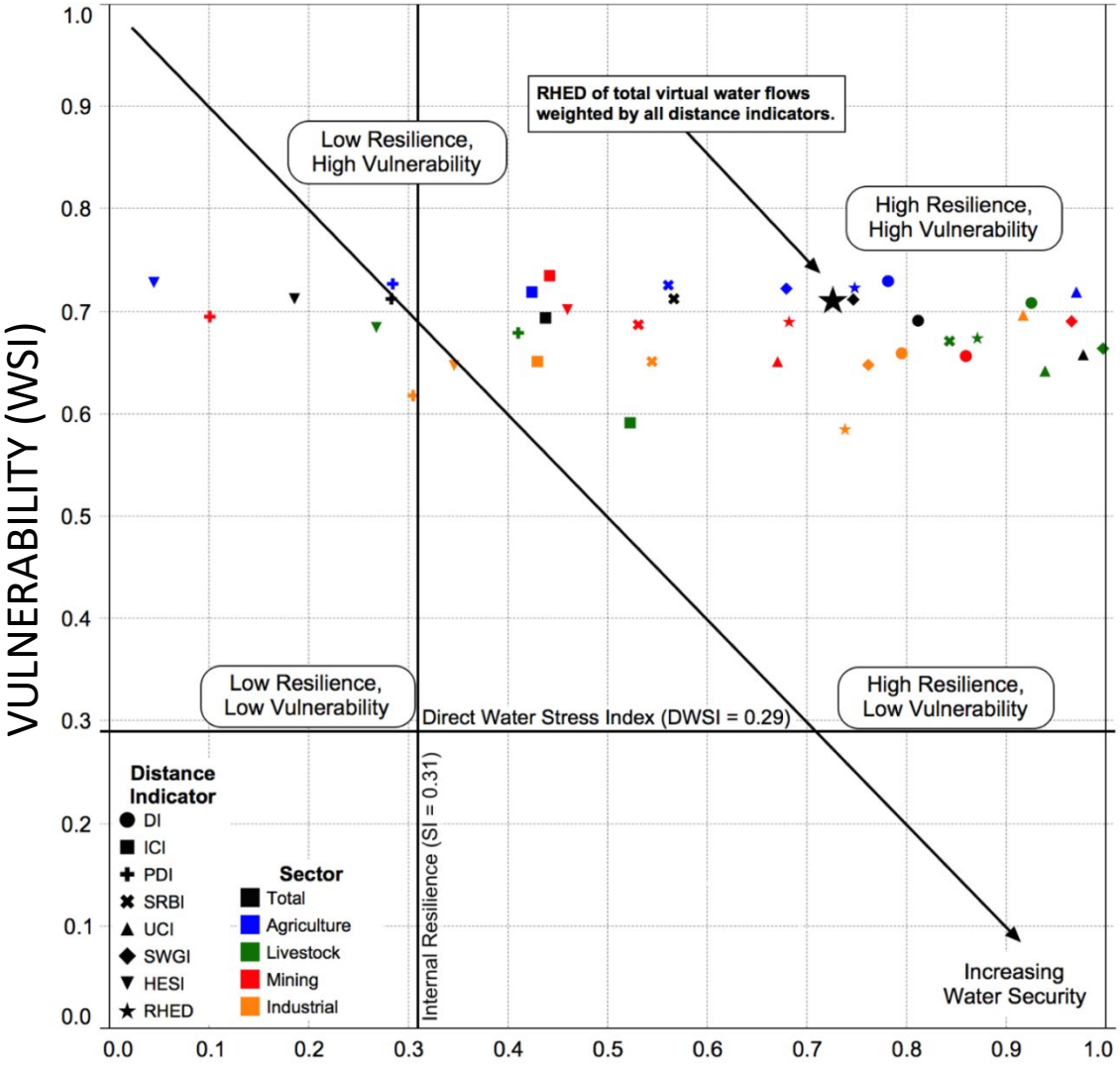
Rushforth, R., and B.L. Ruddell, Urban Water Footprints and Water Sustainability; the water connectivity of Flagstaff, Arizona, Water Resources Research, in review

Resilience Indicators for Flagstaff's Water Supply Chain

- Seven Indicators of Distance
- Resilience based on Shannon Diversity of Distances
- Considers the politics, geography, governance, boundary, hydrological and economic diversity of the water supply chain
- More diverse water supply chains are more resilient to a possible severe drought or water shock in the future



Flagstaff: Vulnerable but also Potentially Resilient to Drought



Where else do we need to anticipate the economic impacts of drought?

- Application: identify locations for investment in water security
- Application: identify people indirectly impacted by a specific drought
- Application: identify places to avoid in the water supply chain

The Syria Conflict and Drought: the region became a food importer

Proceedings of the National Academy of Sciences of the United States of America

CURRENT ISSUE // ARCHIVE // NEWS & MULTIMEDIA // AUTHORS // ABOUT // COLLECTED ARTICLES // BROWSE BY TOP

> Current Issue > vol. 112 no. 11 > Colin P. Kelley, 3241–3246, doi: 10.1073/pnas.1421533112

Climate change in the Fertile Crescent and implications of the recent Syrian drought

Colin P. Kelley[a,1], Shahrzad Mohtadi[b], Mark A. Cane[c], Richard Seager[c], and Yochanan Kushnir[c]

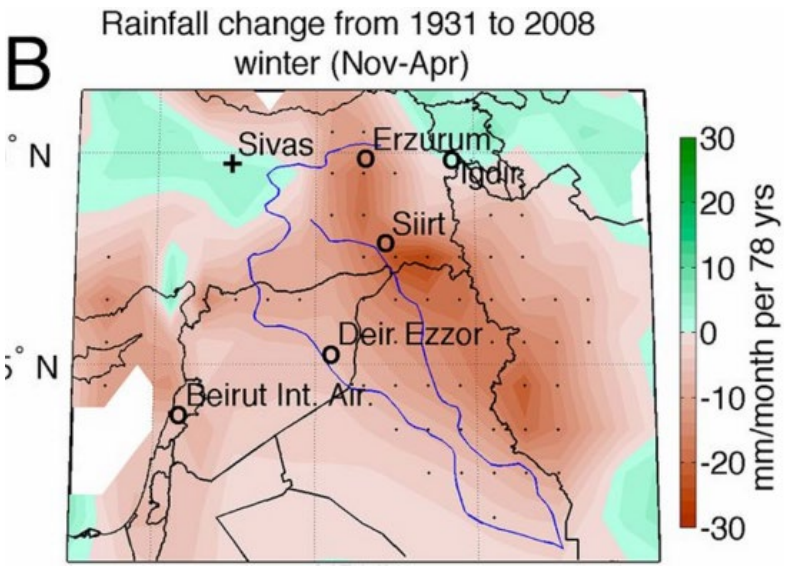
Author Affiliations

Edited by Brian John Hoskins, Imperial College London, London, United Kingdom, and approved January 30, 2015 (received for review November 16, 2014)

Abstract | Full Text | Authors & Info | Figures | SI | Metrics | Related Content | PDF | PDF + SI

Significance

There is evidence that the 2007–2010 drought contributed to the conflict in Syria. It was the worst drought in the instrumental record, causing widespread crop failure and a mass migration of farming families to urban centers. Century-long observed trends in precipitation, temperature, and sea-level pressure, supported by climate model results, strongly suggest that anthropogenic forcing has increased the probability of severe and persistent droughts in this region, and made the occurrence of a 3-year drought as severe as that of 2007–2010 2 to 3 times more likely than by natural variability alone. We conclude that human influences on the climate system are implicated in the current Syrian conflict.



Acknowledgements

Funding Support*

*The views expressed are those of the authors, not necessarily the Sponsors

- U.S. National Science Foundation: NSF-BCS-1026865: *Central Arizona Phoenix Long Term Ecological Research*
- Rob & Melanie Walton Sustainability Solutions Initiative
- Great Lakes Protection Fund grant #946
- WECC via U.S. Department of Energy's Sandia Laboratories

Collaborators

Richard Rushforth (NWED lead contributor)
Elizabeth A. Adams
Seth Herron
Yueming Qiu
Vincent C. Tidwell
Stanley Mubako
Alex Mayer
Doug Toy
Megan Konar, et al.
Alfonso Mejia, et al.
Manu Lall and the America's Water Team
Water Footprint Network
City of Flagstaff
City of Chandler

U.E. National Water Economy Database Methods (NWED-US 1.0)

Water footprint methods giving county-to-county virtual water flows for the United States

- Blue Water, no green (yet), withdrawal-based
- 43 Commodity Types incl. ag, energy, manuf., etc. Aggregated to 5 Economic Sectors: Agriculture, Industry, Livestock, Mining/Energy, and misc. Urban
- (dis)Aggregated to individual municipalities and MSA's
- Complete U.S. water use and economic production are in the water footprint
- Missing from version 1.0 are inter-county service sector and electric trades, and also the virtual water content of foreign-origin commodities (relatively small)

Annual average County Level and Economic Sector data; not seasonal or establishment

- U.S. Commodity Flows – Freight Analysis Framework (FAF3) from Oak Ridge National Labs
- U.S. Water Census- USGS Water Use of the Nation
- U.S. Economic Census
- USDA National Agricultural Statistics Survey

$$F = U + V_{IN} - V_{OUT}$$

U = Water Use
V_{IN} = Virtual Water Inflow
V_{OUT} = Virtual Water Outflow

Contact Us

Homeland Defense & Security Information Analysis Center

Mr. Stuart Stough
HDIAC Director
Oak Ridge, TN
sstough@hdiac.org
(865) 813-1067

Department of Defense Information Analysis Centers

Website: www.hdiac.org
E-mail: info@hdiac.org
Phone: (865) 535-0088

Abstract

A detailed global map of the hydro-economy: water footprints, teleconnections, and indirect security risks of drought

Benjamin L. Ruddell, Ph.D., P.E., Associate Professor, Arizona State University

The global hydro-economic network creates vulnerability to distant drought and water conflict through trade connections. The water footprint maps this water supply chain network. This talk presents the first economically complete and spatially detailed water footprint for a major country: the United States. We also explore the implications of the hydro-economic network for anticipating global business, security, and geopolitical problems in a 21st century characterized by drought, climate change and unsustainable water demands. This information provides important foresight for international business and security interests, allowing us to invest in security and water in the right locations, to anticipate water-induced conflict, and to proactively manage the water supply chain to avoid problems.