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Towards bridging the water gap in Texas: A water-energy-food nexus approach

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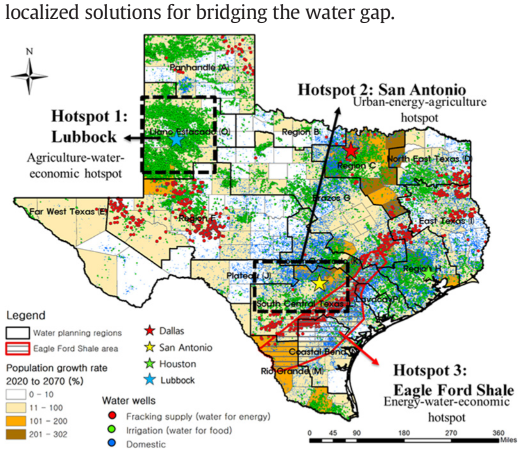
HIGHLIGHTS

- Bridging Texas water gap requires multi-stakeholder, holistic, localized approaches.
- Potential savings of 3 billion gal of water in Lubbock by treating water and dryland agriculture
- Potential of adding 47 billion gallons to water supply in San Antonio by LID implementation
- Economic advantages vs. impact on local water quality and quantity of Hydraulic Fracturing

GRAPHICAL ABSTRACT

Spatially distributed distinct and complex hotspots, which require a holistic system of system approach, yet with localized solutions for bridging the water gap.



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ABSTRACT

The 2017 Texas Water Development Board's State Water Plan predicts a 41% gap between water demand and existing supply by 2070. This reflects an overall projection, but the challenge will affect various regions of the state differently. Texas has 16 regional water planning zones characterized by distinct populations, water demands, and existing water supplies. Each is expected to face variations of pressures, such as increased agricultural and energy development (particularly hydraulic fracturing) and urban growth that do not necessarily follow the region's water plan. Great variability in resource distribution and competing resource demands across Texas will result in the emergence of distinct hotspots, each with unique characteristics that require multiple, localized, interventions to bridge the statewide water gap. This study explores three such hotspots: 1) water-food competition in Lubbock and the potential of producing 3 billion gallons of treated municipal waste water and encouraging dryland agriculture; 2) implementing Low Impact Developments (LIDs) for agriculture in the City of San Antonio, potentially adding 47 billion gallons of water supply, but carrying a potentially high financial cost; and 3) water-

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energy interrelations in the Eagle Ford Shale in light of well counts, climate dynamics, and population growth. The growing water gap is a state wide problem that requires holistic assessments that capture the impact on the tightly interconnected water, energy, and food systems. Better understanding the trade-offs associated with each 'solution' and enabling informed dialogue between stakeholders, offers a basis for formulating localized policy recommendations specific to each hotspot.

1. Introduction

With global population projected to reach 10 billion by 2050 (United Nations, 2017), growing economies (World Bank, 2018), and stresses caused by the impacts of climate change (IPCC, 2014), resource systems are, and will remain, under pressure. In 2017, 844 million people lacked access to safe drinking water; 1.1 billion lacked access to energy; about 815 million did not have secure access to food (WHO, 2017; IEA, 2017; FAO, 2017; Stephan et al., 2018). As a result of the tight interdependence between the growing demands around water, energy, and food systems, resource hotspots will emerge in different regions globally (Hoff, 2011; Mohtar and Daher, 2012; Mohtar and Daher, 2017). Addressing these "Water-Energy-Food Nexus hotspots" requires that we account for the interconnections between them by developing the analytics to catalyze a dialogue about the trade-offs associated with future resource allocation pathway options (Mohtar and Daher, 2016). In this paper, the authors focus on distinct hotspots within the state of Texas in the United States; they develop tools that allow quantification of the interlinkages between water, energy, and food, and explore the trade-offs associated with the different scenarios presented.

The state of Texas risks a 41% (8.9 billion m^3) water gap by 2070, due to projected 70% growth in population between 2020 and 2070, that will increase water demand by 17% and decrease water supply by 11% (TWDB, 2017). In an effort to promote sustainable water management, the Texas Water Development Board (TWDB) issues a 5 year state water plan that includes recommendations for implementation in each of 16 state planning regions. Municipal growth, agricultural expansion, and energy development all combine to place water resources under significant pressure (TWDB, 2017). The Texas cities of Houston, Dallas, San Antonio, and Austin rank among the fastest growing cities in the United States (US) (Forbes, 2015), further increasing pressures on resources and infrastructure. Texas is a major US producer of cattle, dairy, and cotton (USDA, 2016). TWDB predicts that more than 70% of available water will be allocated for irrigation by 2020. As for energy development: Texas contains the Eagle Ford, one of the world's major shale plays, whose shale gas production during the past decade has significantly increased (Murphy et al., 2016).

While revolutionary in terms of providing additional energy security, the hydraulic fracturing industry also puts substantial demand on existing water systems: it is projected that, by 2040, nearly 50% of the total gas production will come from shale resources (USEIA, 2013), for which 5.6 million gallons of water are required, on average, throughout the lifecycle of a well (FracFocus, 2015; Jiang et al., 2014). In the US, natural gas produced from shale resources increased from 0.1 to 3 trillion ft^3 (TCF) during the past decade. Efforts are underway in the hydraulic fracturing industry to reduce those water demands through new technologies. However, such technologies are often more expensive than traditional methods, thus still not commonly used (Brino and Nearing, 2011). The quantity of water needed through the lifetime of a well has been reduced by exploiting opportunities to recycling flowback water (Kondash and Vengosh, 2015; Rassenfoss, 2011). However, groundwater contamination, and the treatment and disposal of "produced water" continue to pose concerns as hydraulic fracturing grows.

The growing competition for water between the three sectors (municipal, energy, and agriculture), and increased stresses such as drought (2015 brought the end of a five-year drought, 2011 was the driest year in the state's recorded history), caused TWDB to dedicate a special section in their new water plan to specifically address drought response projects for the coming years. TWDB proposed a list of 5500 water management strategies meant to boost water supplies and improve conservation and reuse, including desalination and aquifer storage recharge by 2070 (TWDB, 2017).

Each TWDB water planning zone demonstrates different trends of water demand and supply projections. The middle and eastern regions suffer from water scarcity due to high municipal water demands and low surface water availability. Northern Texas requires high water allocation for food production, although ground water (GW) supplies are expected to decrease and alternate sources, such as treated wastewater, are under consideration. South central Texas includes the Eagle Ford shale play, which will demand up to 48,738 m^3 of water for mining by 2020. The main water resource for hydraulic fracturing is GW, projected to decrease by up to 19% between 2000 and 2050.

Planning for and bridging the anticipated water gap demands that existing interconnections with the agricultural and energy sectors be better understood in terms of their spatial and temporal distributions. Although water demanded for mining is less than 5% of the total overall state water demand, this figure is much higher in regions such as the Eagle Ford, often in competition with urban growth and increasing agricultural production.

This work highlights the spatial and temporal attributes of water, energy, and agricultural systems, and quantifies the interconnections and trade-offs among them to identify different pathways forward by:

- **Spatially identifying** the competition for water resource allocation across Texas, given projected population increases, municipal growth, energy development, and expanded agricultural activity;
- **Developing** appropriate tools that follow a water-energy-food holistic assessment methodology to study distinct hotspots and provide trade-offs for informing decision makers;
- **Demonstrating** case studies that represent specific nexus hotspots across the state;
- **Identifying** localized interventions and their potential contributions to bridging the overall Texas water gap.

2. Overarching approach and motivation

The central challenge presented by a growing demand for water is its sustainable allocation across different competing sectors. To provide a solid basis for planning future resource allocations and minimize associated unintended consequences, those areas more prone to resource stress or competition must be identified and assessed for possible interventions and the associated trade-offs. This identification and assessment should be based on understanding the highly interconnected water-energy food (WEF) resource systems. To accomplish this, the authors identify WEF Nexus hotspots across the state of Texas and customize analytics that quantitatively capture the interlinkages between the three resource systems (Daher and Mohtar, 2015), and affecting externalities. Those analytics are then used to facilitate analysis of the trade-offs associated with the pathway options. These analytics will become a powerful tool to facilitate dialogue among stakeholders (Fig. 1).

TWDB data clearly identify areas in which competition exists between municipal, agricultural, and energy sectors. Different "hotspots" have distinct characteristics: resource availability, resource demand,