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Lessons learned: Creating an interdisciplinary team and using a nexus approach to address a resource hotspot

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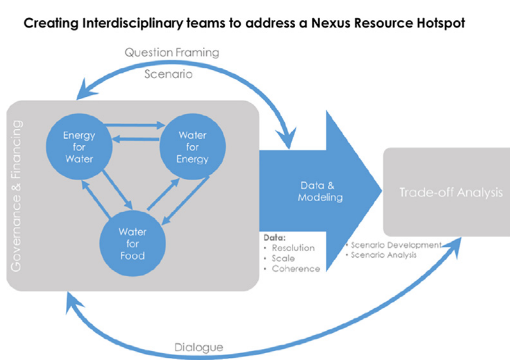
HIGHLIGHTS

- The system-of-systems quantification of water, energy, food, and interconnected systems is similar across hotspots.
- Challenges posed are bound by local knowledge, physical constraints, governance: solutions must be contextualized locally.
- Creating an interdisciplinary team is an iterative process that requires genuine time and energy investment.
- The interdisciplinary approach to developing solutions expands opportunities for economic development and social well-being.

GRAPHICAL ABSTRACT



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ABSTRACT

Moving resource management and allocation away from sectoral silos to a paradigm founded in integration and leveraging cross-sectoral and trans-disciplinary synergies will result in expanded opportunities for economic development and improved social well-being (Mohtar, 2017; Mohtar and Daher, 2017). Interventions to address complex resource challenges must identify opportunities while cognizant of holistic, system level trade-offs (Daher and Mohtar, 2015; Daher et al., 2018a, b, c). These interventions must be contextualized locally: Texas has spatially varied water scarcity, energy resource abundance, and rapid population growth; in the northeastern United States water quality, drainage, and extreme weather events pose far greater challenges. While the overall system-of-systems quantification of water, energy, food and other interconnected systems remains similar across hotspots, the solutions to the challenges posed within each hotspot are bound by local knowledge, physical resource constraints, and governance challenges. This paper introduces the experience of the Texas A&M University Water-Energy-Food Nexus Initiative (WEFNI) in creating a University wide, three-year investigatory experience in which an interdisciplinary group addressed the resource challenges facing the San Antonio region. This Science of the Total Environment (STOTEN) Special Issue documents, in 9 distinct, yet complementary, research articles, the multiple dimensions of this resource hotspot. This paper reflects on the process of creating interdisciplinary teams and presents an overview of the questions and research conducted under thematic foci: data and modeling, trade-off analysis, water for food, water for energy, and governance. Lessons learned from the interdisciplinary experience are presented; potentially transferrable to addressing other resource hotspots within the US, and globally.

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1. Introduction

Growing demands across the interconnected water, energy, and food resource systems express as spatial and thematic “hotspots” that have distinct characteristics which often require unique localized interventions to be addressed. A WEF Nexus “hotspot” is a vulnerable sector or region, with a defined scale and facing stresses in one or more of its resource systems due to resource allocations that are at odds with the interconnected nature of the food, energy, and water resource systems within them (Mohtar and Daher, 2016). The business as usual allocative model for these resources will not be sufficient to address current or anticipated complex and highly interconnected resource challenges. Identifying cross-sectoral synergies (Mohtar and Daher, 2017), adopting a new paradigm for resource management and allocation, moving from silos to nexus integration, are modes of addressing the challenges that will result in expanded opportunities for business growth, economic development, and improved social well-being (Mohtar, 2017). Solutions and interventions must be multi-faceted (Daher et al., 2018a, b, c) and opportunities must be identified, while keeping in mind holistic and system level trade-offs (Daher and Mohtar, 2015; Mohtar and Daher, 2014). Resource Nexus hotspots in Texas, with its spatially varied water scarcity, energy resource abundance, and rapid population growth, differ from hotspots, for example, in the northeastern United States, where water quality, drainage, and extreme weather events pose far greater challenges. The system of systems understanding and quantification of water, energy, food and other interconnected systems is similar across hotspots, however, the solutions and responses to each hotspot is bound by local knowledge, physical resource constraints, and governance challenges.

San Antonio, TX, demonstrates a complex resource hotspot with promising potential: identifying a vision for growth that regards the tight interconnectedness and trade-offs among its WEF resource systems can help realize that potential. Home to both a rapidly growing population in an urbanizing setting and to the Eagle Ford shale play, San Antonio has both increased oil and natural gas production, and major agricultural activity surrounding the city. It comprises a hotspot whose competing demands make it essential that involved stakeholders are properly informed to effectively address future resource challenges. In an effort to ensure the sustainable urbanization of the city, whose growing sectors compete over limited water, land, and financial resources, possible interventions to reduce existing and projected resource stresses must be investigated. In this special issue, the authors build on the existing system of systems understanding and evolution of interconnections within the WEF nexus and propose technological, social, policy, and governance interventions to address the stresses posed. The case studies attempt to identify a vision for multi-faceted interventions that address the complex resource challenges facing the region, while evaluating the trade-offs associated with various pathways forward.

Here, an introduction is shared to the Texas A&M University Water-Energy-Food Nexus Initiative (WEFNI) experience in creating a system wide interdisciplinary group to address the resource challenges facing the San Antonio region. A primary outcome of this three-year investigatory experience is this Science of the Total Environment (STOTEN) Special Issue, which documents in 9 or 10 distinct, yet complementary, research articles that address the multiple dimensions of this resource hotspot. This paper shares the process of creating an interdisciplinary team to address the complex resource challenges facing San Antonio and presents a brief overview of the questions and research conducted under thematic foci that include data and modeling, trade-off analysis, water for food, water for energy, and governance. The conclusion presents lessons learned from the interdisciplinary experience in efforts to better address this hotspot, and replicate elsewhere.

2. Creating the interdisciplinary team to address a WEF Nexus hotspot

The Texas A&M University (TAMU) Water-Energy-Food Nexus Initiative (WEFNI) is a System wide initiative comprising scientists and educators committed to finding solutions to interconnected resource grand challenges (WEFNI, 2018). These scientists and educators make up interdisciplinary teams that share expertise, skill, and scientific abilities to produce the necessary analytics grounded in state-of-the-art science that provide a platform to facilitate inclusive stakeholder dialogue at local, regional and global levels.

2.1. The process of building an interdisciplinary team: sub-groups and their interdependencies

The San Antonio Case Studies (SACS) were launched to support planning for Water-Energy-Food (WEF) Nexus Resources in San Antonio and its surrounding region. Six sub-groups (G) were developed (Fig. 1): G1, Data and Modeling; G2, Energy for Water; G3, Governance and Financing; G4, Trade-off Analysis; G5, Water for Food; and G6, Water for Energy. Each group identified their intended objectives, outcomes, and data collection needs. Following several months of work within the respective sub-groups, a Town Hall style meeting took place with the primary goals of sharing projects, research questions, and data. Potential synergies between sub-groups were discussed, and a nexus interlinkages map (road map) for the overall project was developed. Building on the discussions of the first Town Hall, the framework proposed in Fig. 2 represents the interconnections and interdependencies between the 6 sub-groups. Progress on interlinkages, data and modeling, governance and tradeoffs were made during the first year, however it was concluded that further discussion of stakeholder engagement was needed to develop a stakeholder engagement plan.

Following several full team meetings and regular sub-group and inter-sub-group meetings, a set of highlights and recommendations were identified.

1. Develop a coordinated stakeholder engagement plan.

Fig. 1. The six sub-groups.

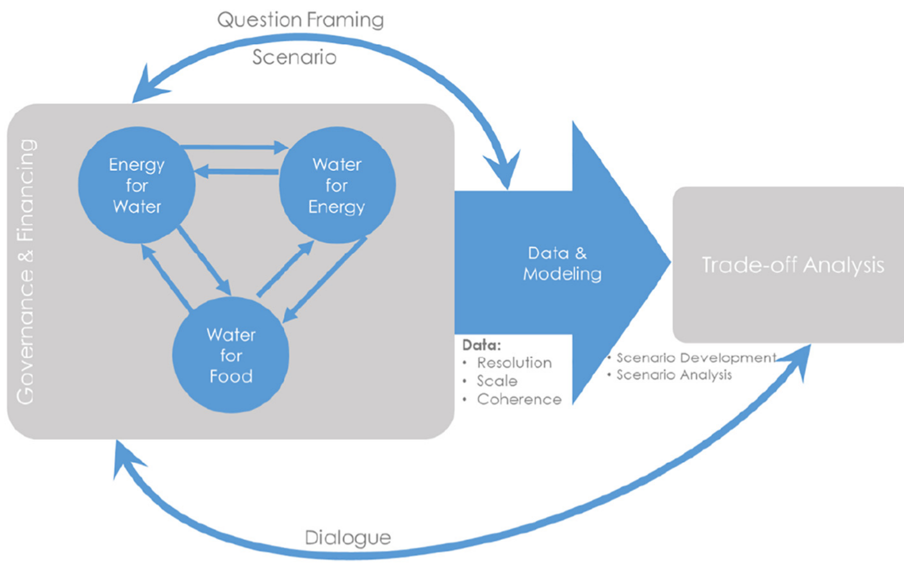

Fig. 2. Sub-groups interdependence and interaction.

2. Joint research activities including proposals and publications, within and across the sub-groups.
3. Pursue both internal and external funding to support the research efforts and the sustainability of these activities.
4. Foster collaborations across WEF disciplines.
5. Target sub-group PI meetings for specific proposal preparation.
6. Schedule bi-weekly WEFNI graduate student meetings to intensify graduate student interaction across groups to ensure/maintain complementarity and improve synergy.
7. Reach out to industry for partnerships and data sharing.
8. Develop a national Water-Energy-Food (WEF) Community of Science to foster interaction; explore the organization of a professional society with an annual meeting at which knowledge and lessons are shared.
9. Identify the nature of a Web portal for data sharing and communication through further discussion.
10. Coordinate future WEF nexus proposals in the coming academic year/s.
11. Hold monthly group meetings (PIs and grad students) for each subgroup.
12. Convene one Town Hall meeting per semester (two per year) to share progress and challenges.

3. Challenges and lessons learned from the process of creating interdisciplinary research

3.1. Challenges

- **Defining the boundaries of the study region**: Even though there was agreement that the San Antonio Region was the resource hotspot of interest, the boundaries of this Region were defined differently across subgroups; iterations and options of boundary definition were discussed. One proposal was to focus the study on Region L, one of 16 water planning regions in the State of Texas for which the Texas Water Development Board (TWDB) issues a 5 year plan outlining its challenges and planned projects. Another was proposed by the hydrologic boundaries intersecting Region L. Options suggested included the boundaries of the San Antonio river basin; a combination of San Antonio, Nueces, and Guadalupe basins; and a combination of Edwards & Southern Carrizo Aquifers. Other boundary definitions included a more governance-centric focus: the boundaries of Groundwater Management Areas (GMA's) and River Authorities (RA) intersecting with water planning region L. Due to the various perspectives, including modeling, governance, utilities, and other needs, it was decided that the San Antonio region definition would be kept open to address these needs, as well as the major WEF stakeholders and geographical hotspots. Fig. 3 provides one example of the different regions: Region L includes Groundwater Management Areas 9, 10, 13 and 15. After discussions across the sub-groups, a consensus was reached that, while different sub-groups might need to focus on different variations of the region to address their respective research questions and objectives, the region of study would predominantly include water planning region L, loosely defined as the "San Antonio Region" (Fig. 3).
- **Identifying dependency maps across sub-groups**: Fig. 4 demonstrates an example of such a map; in this case, in order for group 1 (G1), modeling, to model scenarios, inputs were *needed* from G2, G3, G4, G5, and G6. G1 also *provides* inputs to the governance (G3) and trade-off analysis (G4). The co-identification of those needs across different groups is a process that needs to be both inclusive and iterative.
- **Incompatibility of data across sub-groups**: Different models and tools are commonly used by different sub-groups that focus on various disciplinary perspectives, often either energy centric or water centric. These tools and models require different sets of data and provide different types of outputs at different levels of resolution.
- **Variability in data availability and access across sub-groups**: it is much easier to find hydrological data than, for example, data related to energy.
- **Funding**: Texas A&M funding to kick off the project activities was essential to allow a team of graduate students to be hired to work on the various teams. This seed funding also allowed building partnerships that later successfully competed for funding from the National Science Foundation Innovations in the Food Energy Water Systems (NSF INFEWS) program. Efforts to promote the science and build a community of science and practice are critical for the long term sustainability of this work (WEFNI, 2018).

3.2. Transferable lessons learned

Reflections and lessons learned from SACS experience include:

- **It is an iterative processes**. While time consuming, it was necessary to arrive at consensus across the sub-groups to achieve convergence toward the project goals and objectives.

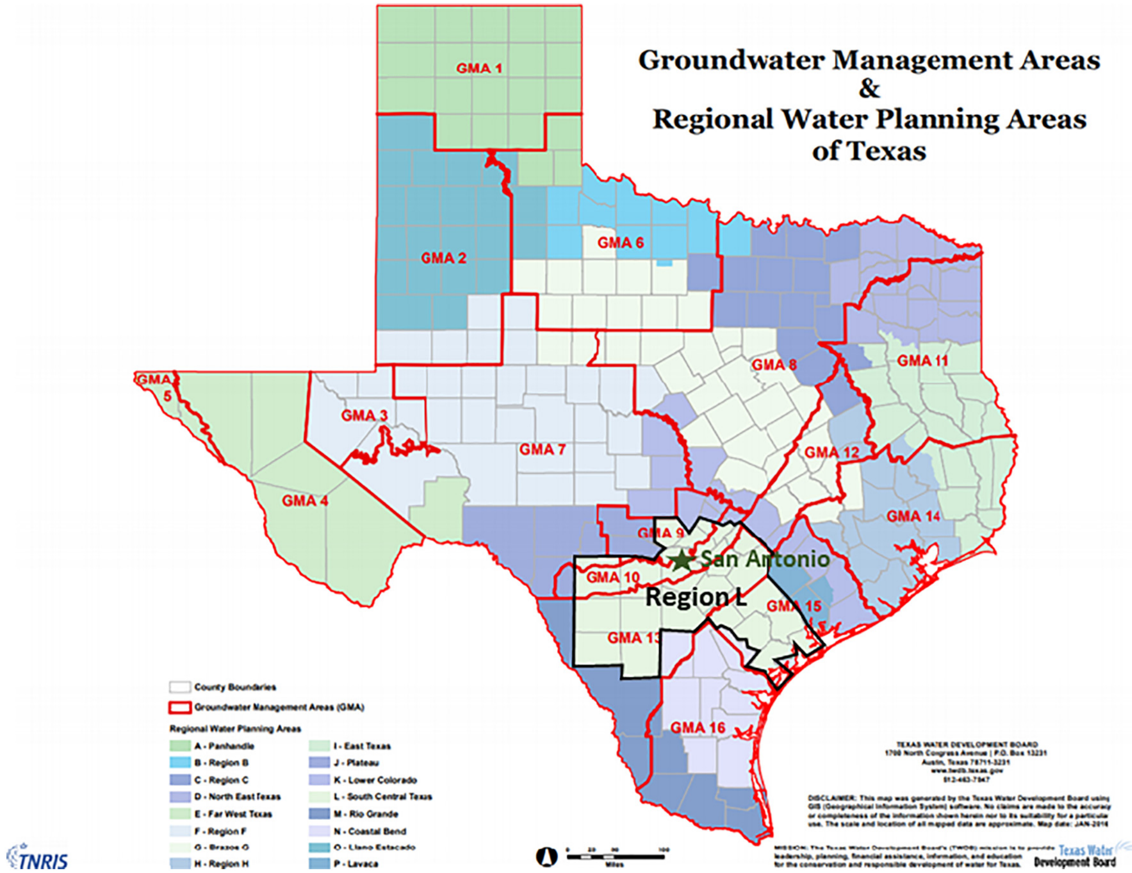

Fig. 3. Water Planning Region L and overlapping GMA's (TWDB, 2018).

- **Investment of time and effort are essential to building genuine, honest, one on one relations**. While agreement on overarching objectives and goals is important, unless complemented with different levels of follow up and the investment of time, the project outcomes could be jeopardized.
- **Differences in perspectives across disciplines exist**: identifying synergistic goals and understanding the interdependencies between sub-groups require a clear definition of the duties and scope across sub-groups.
- Outcomes and progress must be **communicated beyond the disciplinary circle** to include the sub-groups.
- **Tone down disciplinary egos**: the final product is dependent upon everyone participating collectively in the process, not relying solely on disciplinary knowledge

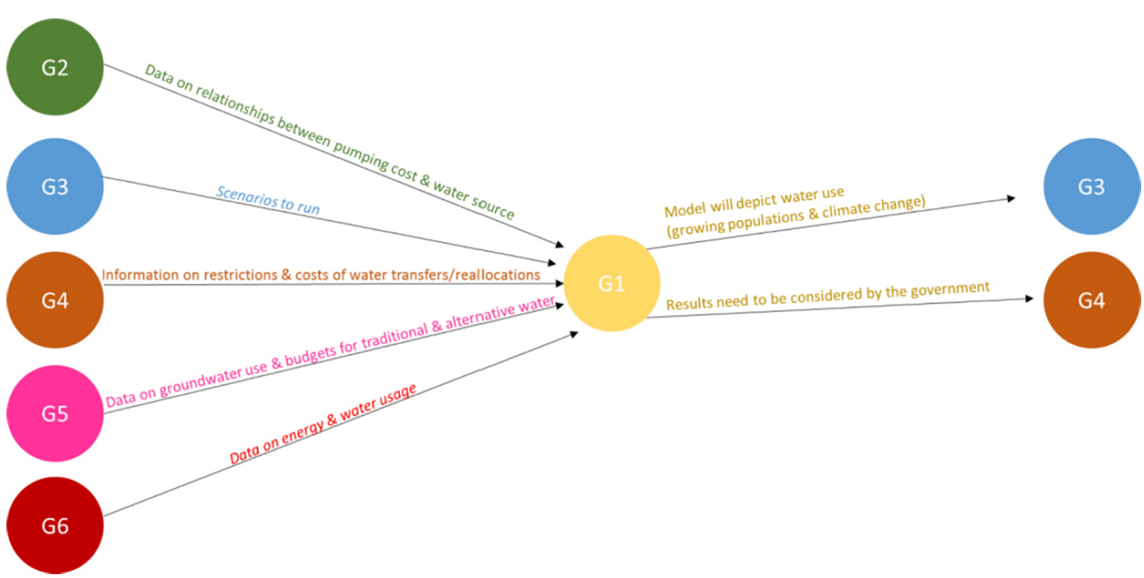

Fig. 4. Example of dependency maps between sub-groups.

- The **process requires time, effort, and multiple iterations**; discomfort, not fully understanding everything being developed by teams from other disciplines is part of the process.

4. The STOTEN special issue

The issue comprises 9 papers and this introductory piece. It brings together the work of graduate students and their respective PI teams of faculty mentors. The issue reflects the outcomes of two general stakeholder engagement meetings and several town halls, all convened in an effort to better understand the challenges and the benefits of crossing disciplinary and sectoral boundaries to achieve a holistic understanding of the challenges facing resource management and allocation. The 9 papers are briefly described below, according to the over-arching subject of their research focus.

4.1. Modeling

In the article *Complexity versus Simplicity in Water Energy Food Nexus* (*WEF*) *Assessments*, Dargin et al. (2018), a *complexity index* for WEF Nexus assessment tools that builds upon the System Usability Scale (SUS) concept was produced. Scatter-plots are used to convey complexity relationships and serve as a preliminary guideline in selecting nexus tools specific to user-defined objectives. The lack of nexus applications in policy and decision making is related to several factors: the main barrier being the complex nature of “nexus” systems and the disarray of tools attempting to model those interconnections. Results suggest that tools with higher complexity scores, while able to capture details of specific resource interactions, are unable to cover larger numbers of interactions and system components simultaneously. The analysis points to the need to integrate more preliminary assessment capabilities, *i.e.* diagnostics, guidelines, and capacity building, into existing tools to improve the communication and translation of model outputs into policy and decision-making.

4.2. Trade-off analysis

In the article, *Towards bridging the water gap in Texas: A Water-Energy-Food Nexus Approach*, Daher et al. (2018a, b, c), different multi-stakeholder, holistic, localized solutions for bridging the anticipated water gap in Texas are investigated. The 16 regional water planning zones of Texas are characterized by distinct populations, water demands, and existing water supplies. This study explores three hotspots: 1) water-food competition in the City of Lubbock and the potential of bridging the projected gap through treating waste water and encouraging dryland agriculture; 2) implementation of Low Impact Developments (LIDs) for agriculture in the City of San Antonio, potentially adding 47 billion gallons to water supply, but carrying a potentially high cost; and 3) water-energy interrelations in the Eagle Ford shale play in light of oil and gas well counts, climate change, and population growth. A better understanding of the trade-offs associated with each ‘solution’ can inform dialogue between stakeholders and offer a basis to guide policy recommendations in each hotspot.

Mohtar et al. (2018), in their article, *Economic, Social, and Environmental Evaluation of Energy Development in the Eagle Ford Shale Play*, 1) quantify the interconnections between water, energy, and transportation systems specific to the Eagle Ford shale region; 2) identify and quantify the economic, social, and environmental indicators to evaluate scenarios of oil and gas production; and 3) develop a framework for analysis of the economic, societal, and long term sustainability of the sectors and 4) an assessment tool (WET Tool) that estimates several economic indicators: oil and natural gas production, direct and indirect tax revenues, and average wages for each scenario facilitates the holistic assessment of oil and gas production scenarios and their associated trade-offs between them. While the economic benefits are straightforward, the social costs of shale development (water consumption, carbon emissions, and transportation/infrastructure factors), are difficult to quantify.

4.3. Water and energy

Bhojwani et al. (2018), in *Technology review and data analysis for cost assessment of water treatment systems*, provide a comprehensive and comparative review of the water management systems and their associated economic, environmental, and performance metrics. The systems are presented as a network of sources, users, technologies, recycling options, and quality of water. Special attention is given to desalination systems. The cost assessment includes a capital cost comparison, an operating cost comparison, and a maintenance and repair costs comparison. Multivariate statistical methods were used to analyze collected data to understand the relationship to capital cost, operating cost, capacity, constraints due to treatment method capabilities, requirements of the users.

Mroue et al. (2018), in *Energy Portfolio Assessment Tool* (*EPAT*): *Sustainable energy planning using the WEF nexus approach - Texas case*, present a scenario-based holistic nexus tool Energy Portfolio Assessment Tool (EPAT) for energy policy and portfolio sustainability tradeoff evaluation, providing a platform for energy stakeholders and policymakers to create and evaluate the sustainability of various scenarios based on the water-energy-food (WEF) nexus approach. Conservation policies should move from the silo to the nexus mentality to avoid unintended consequences that result in improving one part of the nexus while worsening the other parts.

4.4. Water for food

Loy et al. (2018), in *Effect of municipal treated wastewater and brackish groundwater on the hydrostructural properties of a clayey, calcareous soil*, investigate treated wastewater and brackish groundwater as alternative sources to fresh water for agricultural irrigation, and the effects of these practices on soil. Field capacity, permanent wilting point, and available water are indicators of a soil's health and ability to provide water for plants. Treated wastewater and groundwater decreased the soil's water-holding ability in the lower horizons of this soil (clayey calcareous, below 15–72 cm), while rain fed soil retained the best ability to hold water for plants. Treated wastewater can serve as a suitable alternative to groundwater in this agricultural area, as it does not degrade soil properties any more than the groundwater and produces higher yields for the farmer. Every water source and soil combination is different, so water conservation practices and implications require localized analysis and conclusions.

Tahtouh et al. (2018), in *Impact of brackish groundwater and treated wastewater on soil chemical and mineralogical properties*, study the impact of irrigation with non-traditional water (TWW and BGW) on the chemical and mineralogical properties of a calcareous clayey soil from West Texas. TWW has a better quality than the BGW of the local aquifer. TWW and BGW are viable substitute for freshwater irrigation in arid regions. TWW and BGW samples were collected and analyzed salt and nutrient content. Soil samples from three horizons (Ap, A, and B) were obtained from three different fields: Rainfed (RF), BGW irrigated, and TWW irrigated. Soil was analyzed for texture, salinity, sodicity, and carbon content. Clay mineralogy of the three different fields were analyzed using the B-horizons. The outcomes show that TWW and BGW are viable replacements for freshwater irrigation in arid and semi-arid regions.

4.5. Governance

Despite the tight interconnectedness between water, energy, and food challenges, little is known about the levels of communication and coordination between the various officials responsible for making the decisions affecting the management and planning of the three resource systems.

Daher et al. (2018a, b, c) in *Towards creating an environment of cooperation between water, energy, and food stakeholders in San Antonio*, investigate the level of communication between water, energy, and food stakeholders in the San Antonio. A questionnaire was mailed to 289 public water officials in the Region; 101 responses were received. Analysis of the responses led to the conclusion that while modest levels of communication exist between water institutions, a very low level of communication exists between water institutions and those responsible for food and energy. The frequency of communication between and among water officials at different water and planning institutions is higher among those that participate in stakeholder engagement activities. There was insufficient evidence to suggest that participation in stakeholder engagement activities actually improves communication frequency between water stakeholders and those in the food and energy sectors.

Aldaco-Manner et al. (2018), in *Analysis of four governance factors on water governing agencies' efforts to increase water reuse in the San Antonio Region* identify key governance factors contributing to increasing water reuse within the water planning sector and tests four governance-related hypotheses for their impact on efforts to increase water reuse in the Region, including the type and scale of water governance agency, the agency's frequency of communication with the TWDB, and the agency's familiarity with the TWDB water strategy supplies as defined in the Texas State Water Plan of 2017. Results indicate that nearly 70% of agencies in the regions have efforts to increase water reuse by as much as 10%. Among the tested hypotheses, frequency in communication with the TWDB was statistically significant for increasing agency efforts to reuse water. Results from these hypotheses are expected to help water managers identify key, governance-related factors that contribute to increased water reuse.

5. Conclusions

No single discipline or area of research focus is sufficient to address the interconnected, complex resource challenges faced today. Unless the knowledge and expertise of each of these disciplines is brought to address these challenges, important aspects of each may be overlooked, bringing unintended consequences. At the same time, working synergistically and across the siloes of disciplinary work, builds a deeper understanding of the issues and challenges and promotes a pathway to discovery that includes holistic solutions that will encourage long term sustainability of resource allocation. This special issue documents the experience of understanding such a complex resource hotspot in San Antonio, Texas, with the goal of sharing experiences transferrable to other hotspots within the US and other resource stressed regions globally.

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