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WEBINAR

Opportunities of the WEF Nexus Approach:

Innovatively driving economic development, social wellbeing, and environmental sustainability

Webinar | 8:30-10:30AM (CST), 4:30-6:30PM (Beirut Time) | Nov 27, 2018

Webinar Goals and Outline

Share progress and plans for the
Water-Energy-Food Nexus Consortium

Share outcomes of **11 research articles** documenting WEFNI's experience in addressing a WEF Nexus hotspot in San Antonio Texas

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Share information on the new initiative at
The American University of Beirut: WEFRAH

WEFRAH
Water-Energy-Food-Health Nexus
Renewable Resources Initiative

WEF Nexus Consortium Objectives

1) Share WEF Nexus lessons learned across scales and sectors toward implementation of the SDGs.

2) Facilitate dialogue between the stakeholders about the role of WEF Nexus in implementation of SDGs: funding agencies, banks, academics, private and public sectors, technology providers, entrepreneurs and civil society.

3) Discuss ways to improve policy coherence across WEF sectors and scales.

WEF Nexus Consortium Milestones

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IFPRI INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE
Global Water Partnership
OCP POLICY CENTER
IWRA
gef GLOBAL ENVIRONMENT FACILITY INVESTING IN OUR PLANET
NSF
AUB American University of Beirut
Food and Agriculture Organization of the United Nations
IWMI International Water Management Institute
WWF
IUCN
circle of blue
UNITED NATIONS UNIVERSITY UNU-FLORES
Water for Food ROBERT B. DAUGHERTY INSTITUTE University of Nebraska
ICID•CIID
SEI STOCKHOLM ENVIRONMENT INSTITUTE
WATER FOUNDRY
ADB ASIAN DEVELOPMENT BANK
THE WORLD BANK
giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
Water JPI
WORLD WATER COUNCIL
IWA the international water association

Outcomes and Moving Forward

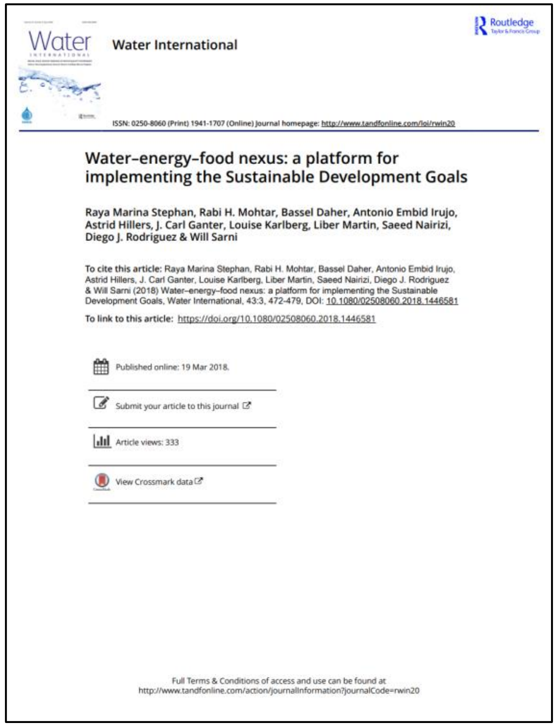
MOVING FORWARD

1. SDG case studies at different scales
2. Establish a WEF Nexus community of science and practice
3. Expand on system's approach for understanding interconnected resource challenges
4. The genie is out!
5. Explore policy, technological, social interventions
6. Education and capacity building

OUTCOMES

Daher, B., Mohtar, R.H., Davidson, S., Cross, K., Karlberg, L., Darmendrail, D., Ganter, C.J., Kelman, J., Sadoff, C., Nahon, C., Fonseca, G., Comby, J., Lavarde, P., Abicalil, T., Aldaco-Manner, L., Schweitzer, M. (2018). Multi-stakeholder Dialogue: Water-Energy-Food (WEF) Nexus and Implementing the SDGs. IWRA Policy Brief No. 2

Stephan, R. M., Mohtar, R. H., Daher, B., Irujo, A. E., Hillers, A., Ganter, J. C., Karlberg, L., Martin, L., Nairizi, S., Rodriguez, D. J., & Sarni, W. (2018). Water–energy–food nexus: a platform for implementing the Sustainable Development Goals, Water International, doi: 10.1080/02508060.2018.1446581


Water International

Routledge Taylor & Francis Group

ISSN: 0250-8060 (Print) 1941-1707 (Online) Journal homepage: http://www.tandfonline.com/loi/rwin20

Water–energy–food nexus: a platform for implementing the Sustainable Development Goals

Raya Marina Stephan, Rabi H. Mohtar, Bassel Daher, Antonio Embid Irujo, Astrid Hillers, J. Carl Ganter, Louise Karlberg, Liber Martin, Saeed Nairizi, Diego J. Rodriguez & Will Sarni

To cite this article: Raya Marina Stephan, Rabi H. Mohtar, Bassel Daher, Antonio Embid Irujo, Astrid Hillers, J. Carl Ganter, Louise Karlberg, Liber Martin, Saeed Nairizi, Diego J. Rodriguez & Will Sarni (2018) Water–energy–food nexus: a platform for implementing the Sustainable Development Goals, Water International, 43:3, 472-479, DOI: 10.1080/02508060.2018.1446581

To link to this article: https://doi.org/10.1080/02508060.2018.1446581

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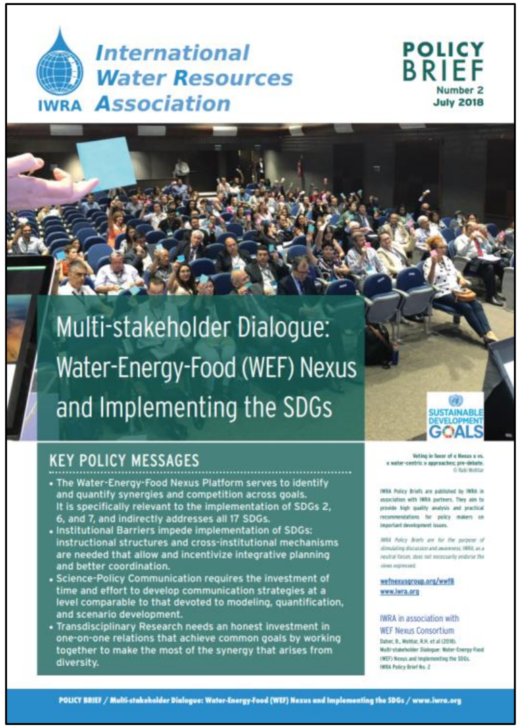
World Water Congress
(Stephan et al., 2018)



World Water Forum
(Daher et al., 2018)

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Science of the Total Environment Special Issue

Guest Editor: Rabi H. Mohtar

Opportunities of the WEF Nexus Approach:

Innovatively driving economic development, social wellbeing, and environmental sustainability

Webinar | 8:30-10:30AM (CST), 4:30-6:30PM (Beirut) | Nov 27, 2018

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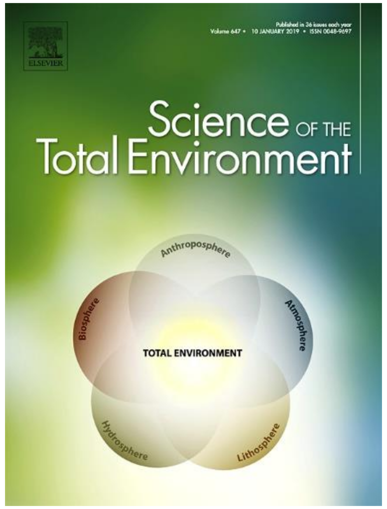

Lessons learned: Creating an interdisciplinary team and using a nexus approach to address a resource hotspot

Rabi H. ***Mohtar*** *& Bassel* ***Daher***

Opportunities of the WEF Nexus Approach:

Innovatively driving economic development, social wellbeing, and environmental sustainability

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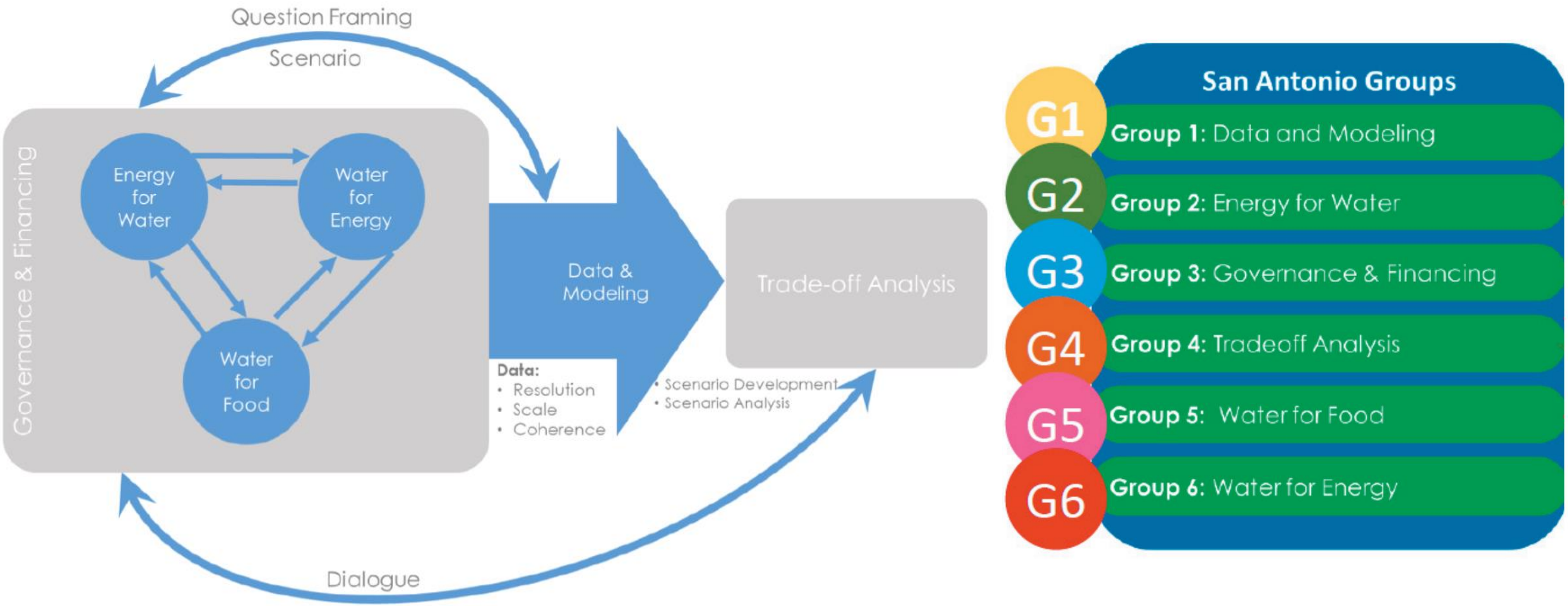
Creating an Interdisciplinary Team



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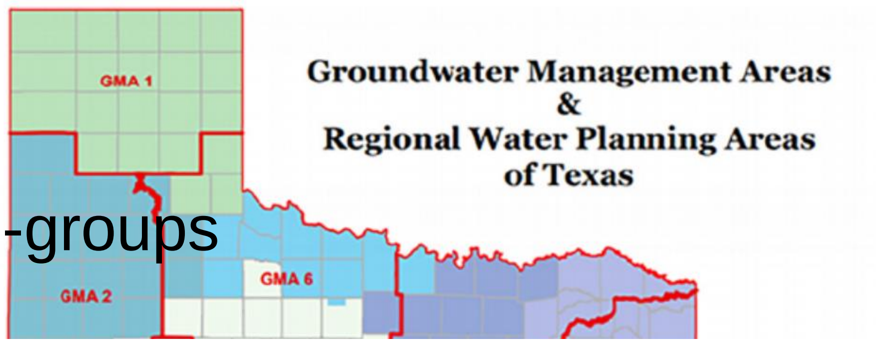
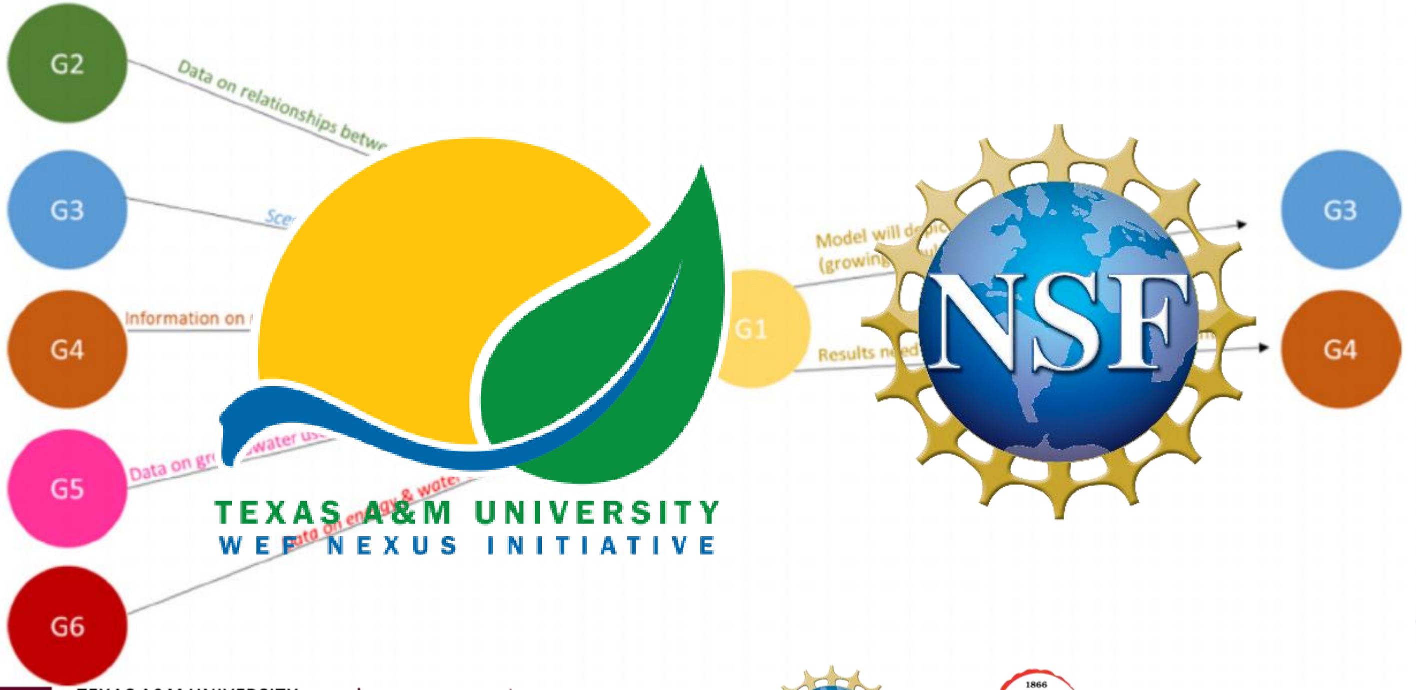
Challenges

1. Defining the boundaries of the study region
2. Identifying dependency maps across sub-groups
3. Incompatibility of data across sub-groups
4. Variability in data availability and access across sub-groups
5. Sustainable financing





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Lessons Learned

1. It is an iterative process.
2. Investment of time and effort are essential to building genuine, honest, one on one relations.
3. Differences in perspectives exist across disciplines.
4. Outcomes and progress must be communicated *beyond* the disciplinary circle to include the sub-groups.
5. Tone down disciplinary egos.
6. Process requires time, effort, and multiple iterations.

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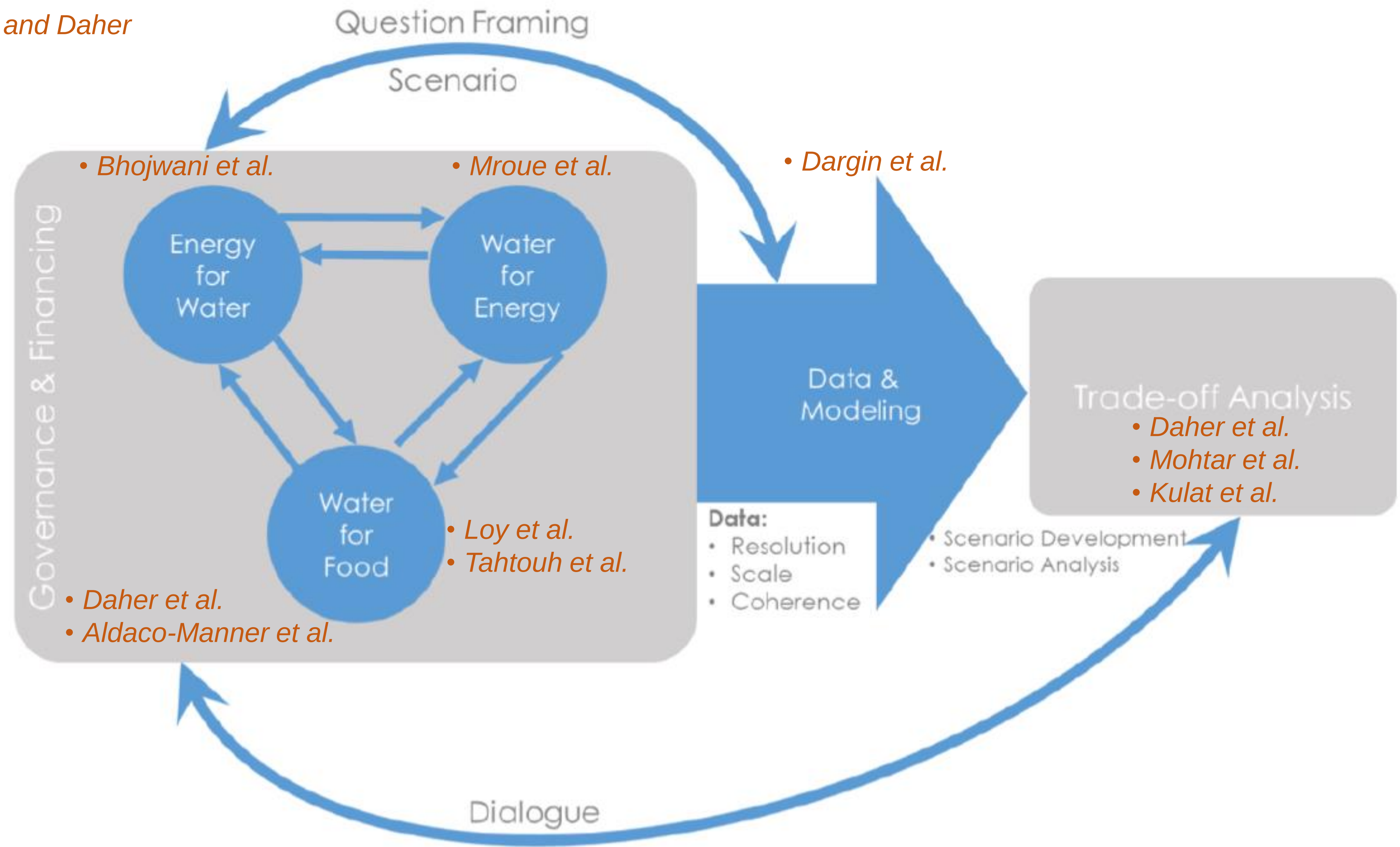
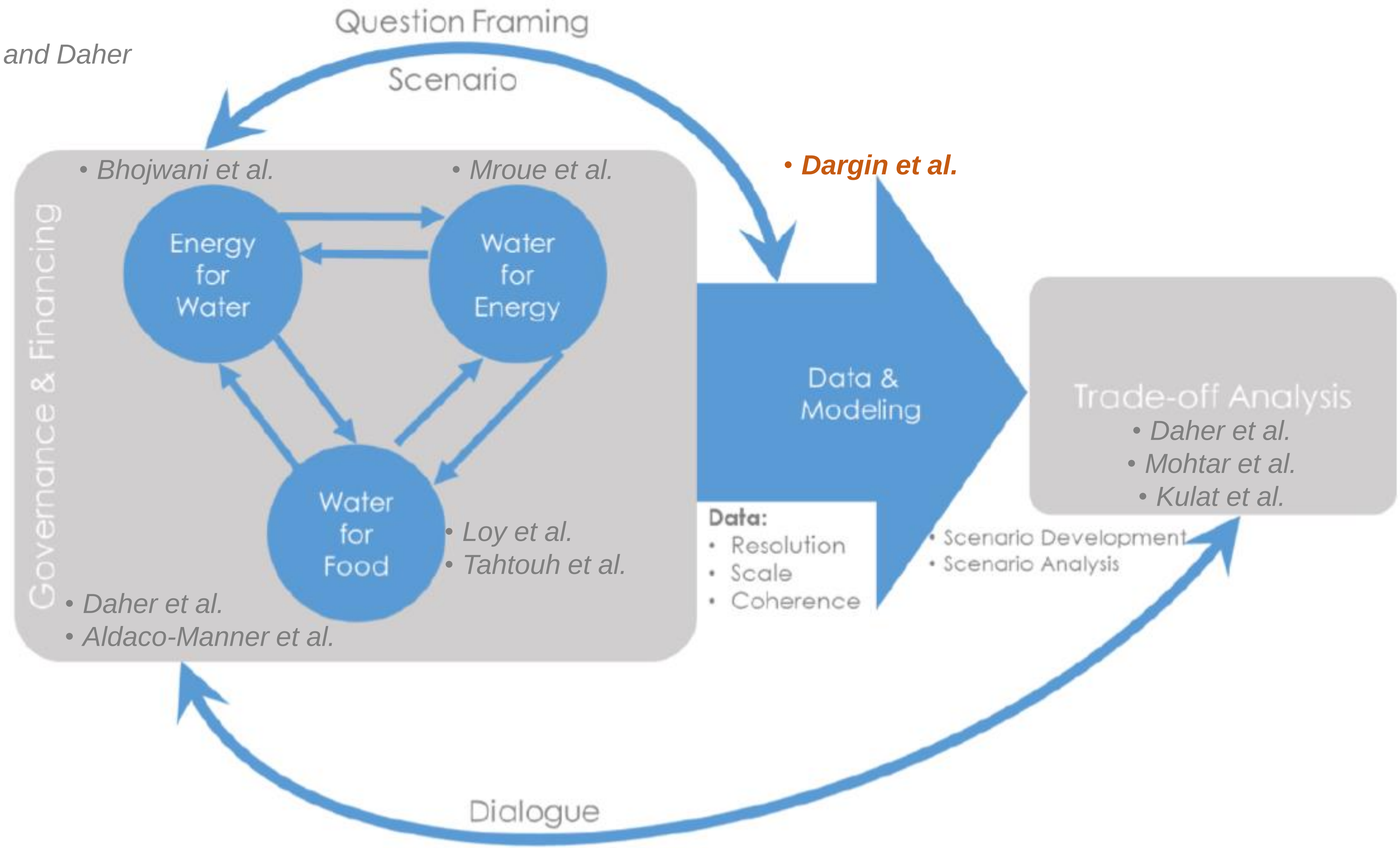
- Mohtar and Daher



- Bhojwani et al.
- Mroue et al.
- Dargin et al.
- Loy et al.
- Tahtouh et al.
- Daher et al.
- Aldaco-Manner et al.
- Daher et al.
- Mohtar et al.
- Kulat et al.

- Mohtar and Daher



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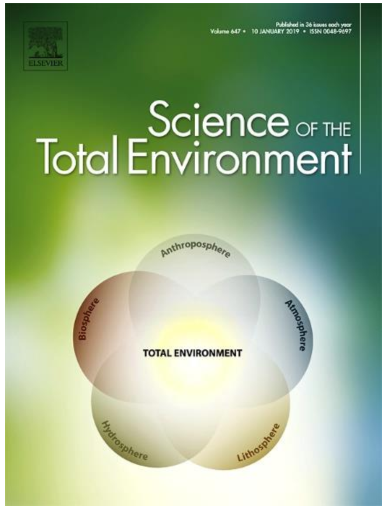


Complexity versus Simplicity in Water Energy Food Nexus (WEF) Assessment Tools

Jennifer ***Dargin****, Bassel* ***Daher****, Rabi H.* ***Mohtar***

Opportunities of WEF Nexus Approach:

Innovatively driving economic development, social wellbeing, and environmental sustainability

Webinar | 8:30-10:30 AM (CST), 4:30-6:30 PM (Beirut) | Nov 27, 2018

Background and Study Objectives

Bringing forward a new perspective on the notion of simplicity and complexity among nexus assessment tools

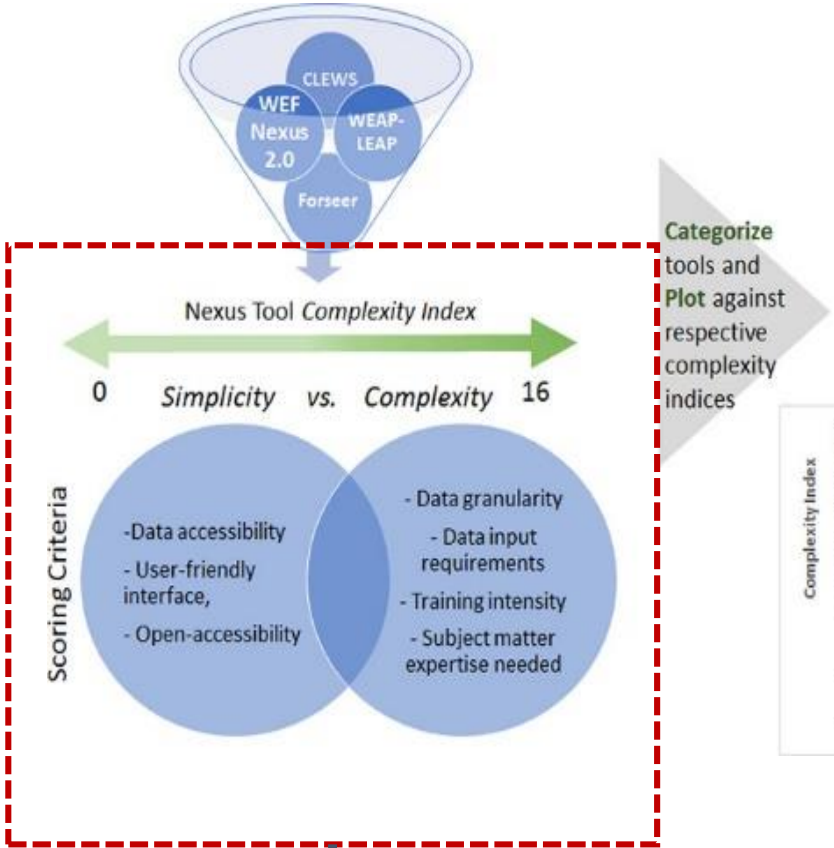
Defining simplicity & complexity within the scope of Nexus Management Tools → Developing an index → Visualizing tool applications & tradeoffs

What are the key factors that contribute to complexity?

How to quantify and score tool complexity?

How can we make the results interpretable by a general audience?

Methods



			Strongly Disagree 1	2	3	4	Strongly Agree 5
1	I think that I would like to use this system frequently.						
2	I found the system unnecessarily complex.						
3	I thought the system was easy to use.						
4	I think that I would need the support of a technical person to be able to use this system.						
5	I found the various functions in this system were well integrated.						
6	I thought there was too much inconsistency in this system.						
7	I would imagine that most people would learn to use this system very quickly.						
8	I found this system very awkward to use.						
9	I felt very confident using this system.						
10	I needed to learn a lot of things before I could get going with this system						

System Usability Scale (SUS) for user assessment of models and computer systems (Lewis, 2018)

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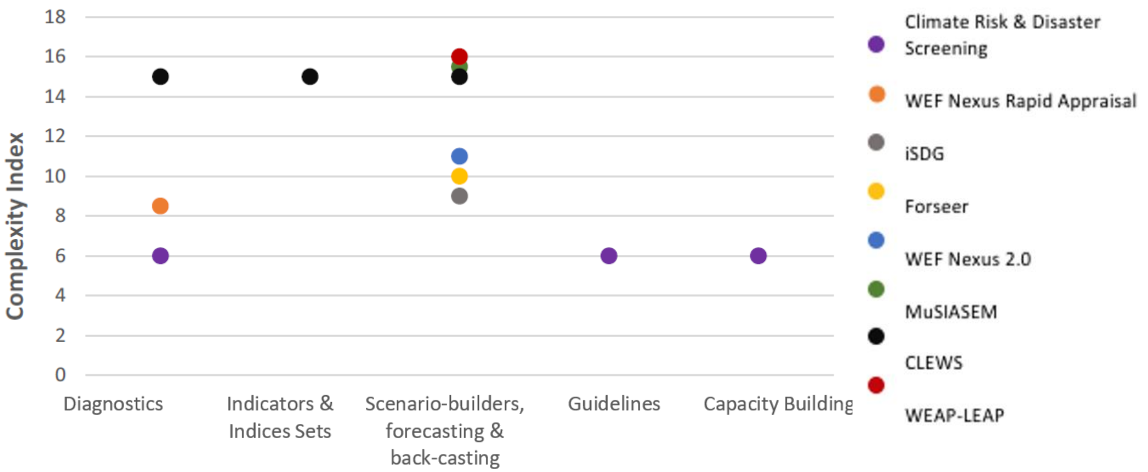
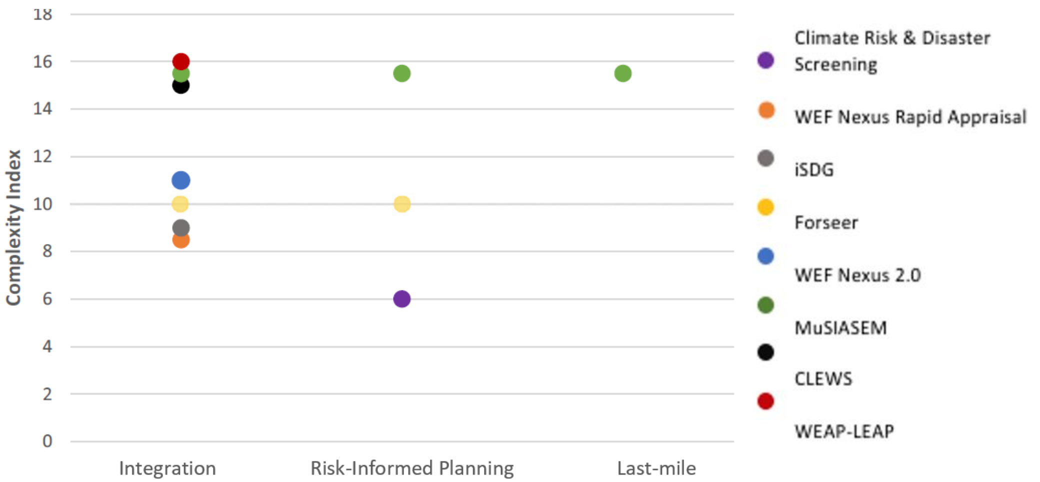
Results

Nexus Tool	Complexity Index	Tool Purpose	Tool Methodology	Tool Scope	Externalities
WEF Nexus Rapid Appraisal	8	Indicators and Indices sets; Capacity building	Integration Tool	W-E-F	Socioeconomics, Climate Change
World Bank Climate and Disaster Risk Screening Tools	6	Diagnostics	Risk-Informed Planning	W-E-F	Climate Change
iSDG Planning Model	9	Scenario-builders, forecasting & back-casting	Integration	W-E-F	Socioeconomics
Foreseer	10	Scenario-builders, forecasting & back-casting	Integration; Risk Informed Planning	W-E	Climate Change; Socioeconomics
WEF Nexus Tool 2.0	11	Scenario-builders, forecasting & back-casting	Integration Tools	W-E-F	
MuSIASEM	15	Scenario-builders, forecasting & back-casting	Integration Tool	W-E-F	Socioeconomics
CLEWS	15.5	Diagnostics; monitoring indicators and indices, scenario builders, forecasting and back-casting	Integration Tools; Last-mile; Risk-Informed Planning	W-E-F	Climate Change
WEAP-LEAP Integrated Model	16	Scenario-builders, forecasting & back-casting	Integration	W-E	

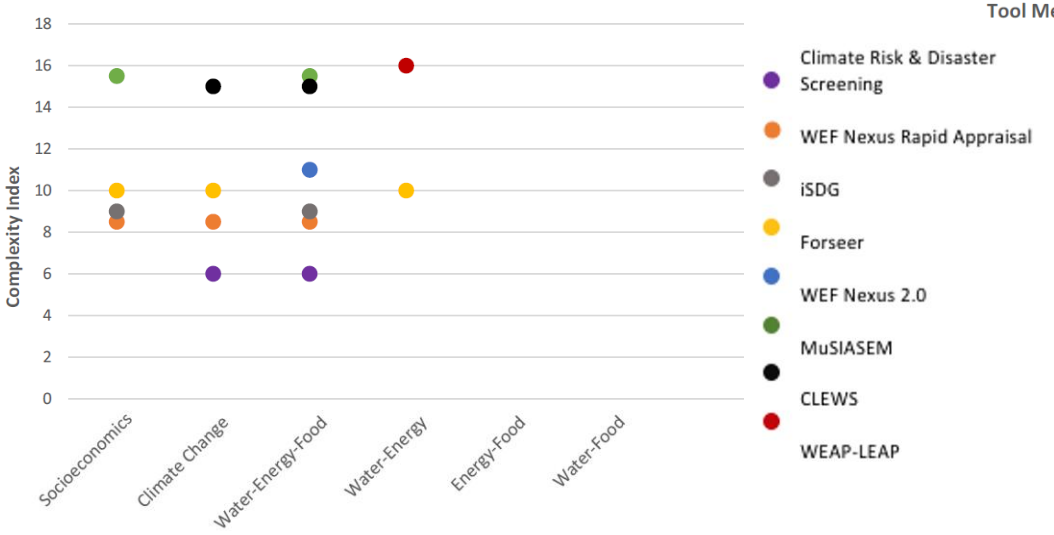
Results



Tool Purpose



Tool Methodology



Nexus Scope & Externalities

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Key Messages

- Higher complexity ≠ superior ; lower complexity ≠ better

- Trade-offs for using different tools

simplicity

- low data needs
- rapid assessments
- capacity building/educational
- role in identifying hotspots/initial assessment stages

- Different purpose
- Different scopes
- Different methodologies

complexity

- time, resources, capacity
- assess more detailed questions
- data needs

- Moving forward: Increase *coordination* and *collaboration* to *avoid repetition* in methodologies and tool development

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Q&A 1

Introduction (5 min)

CST: 8:37 am | Beirut: 4:37 pm

Mohtar, R. H., & Daher, B. (2019). Lessons learned: Creating an interdisciplinary team and using a nexus approach to address a resource hotspot. Science of the Total Environment, 650, 105-110. doi:10.1016/j.scitotenv.2018.08.406

Modeling (10 min)

CST: 8:42 am | Beirut: 4:42 pm

Dargin, J., Daher, B., and Mohtar, R. H. (2019). Complexity versus simplicity in water energy food nexus (WEF) assessment tools. Science of the Total Environment, 650, 1566-1575. doi:10.1016/j.scitotenv.2018.09.080

Q/A

Opportunities of the WEF Nexus Approach:
Innovatively driving economic development, social wellbeing, and environmental sustainability

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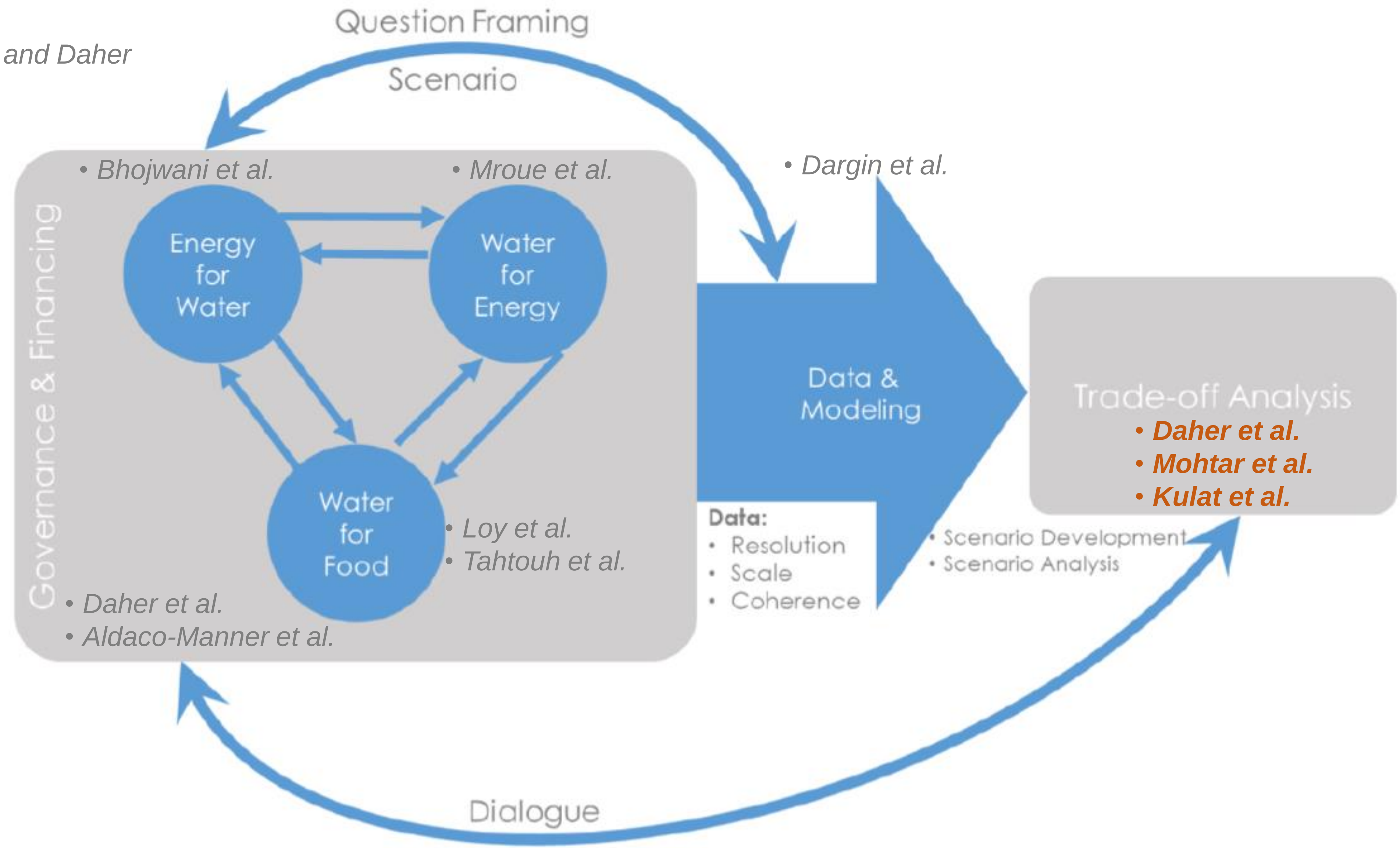
- *Mohtar and Daher*



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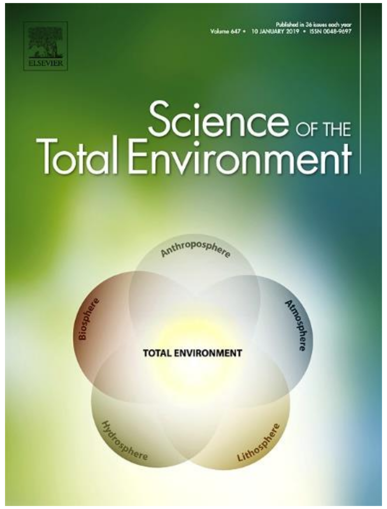

Towards bridging the water gap in Texas: A water-energy-food nexus approach

*Bassel **Daher**, Sang-Hyun **Lee**, Vishakha **Kaushik**, John **Blake**, Mohammad H. **Askariyeh**, Hamid **Shafiezadeh**, Sonia **Zamaripa**, Rabi H. **Mohtar***

Opportunities of the WEF Nexus Approach:

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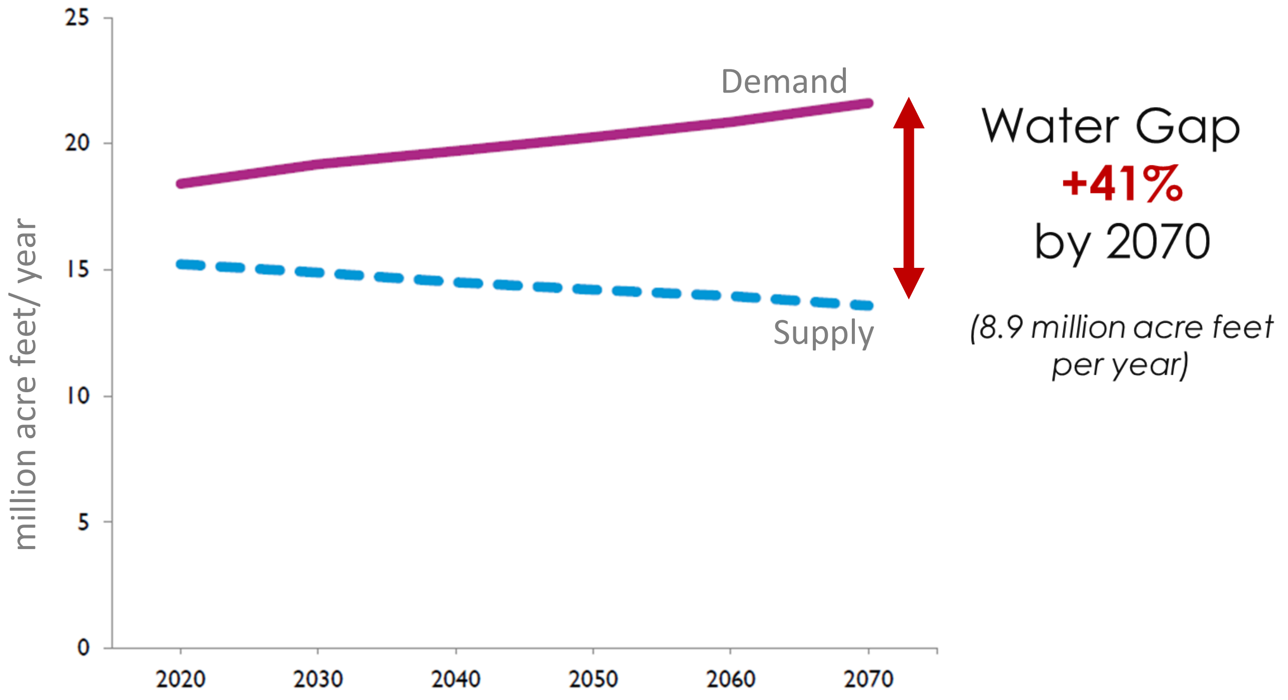
Webinar | 8:30-10:30 AM (CST), 4:30-6:30 PM (Beirut) | Nov 27, 2018

Background and Study Objectives



How might we bridge the **Texas water gap,**
given the projected **population growth** & **climate change stresses**,
while accounting for
variable water availability and **water demanding sectors**
across **different regions** of the state?

OBJECTIVES

1. **Spatially identify** the competition for water resource allocation across Texas, given: projected population increases, municipal growth, energy development, and expanded agricultural activity.

2. **Develop appropriate tools** that follow a water-energy-food holistic assessment methodology to study distinct hotspots and provide trade-offs for informing decision makers.

3. **Identify localized interventions** and their potential contributions to bridging the overall Texas water gap.

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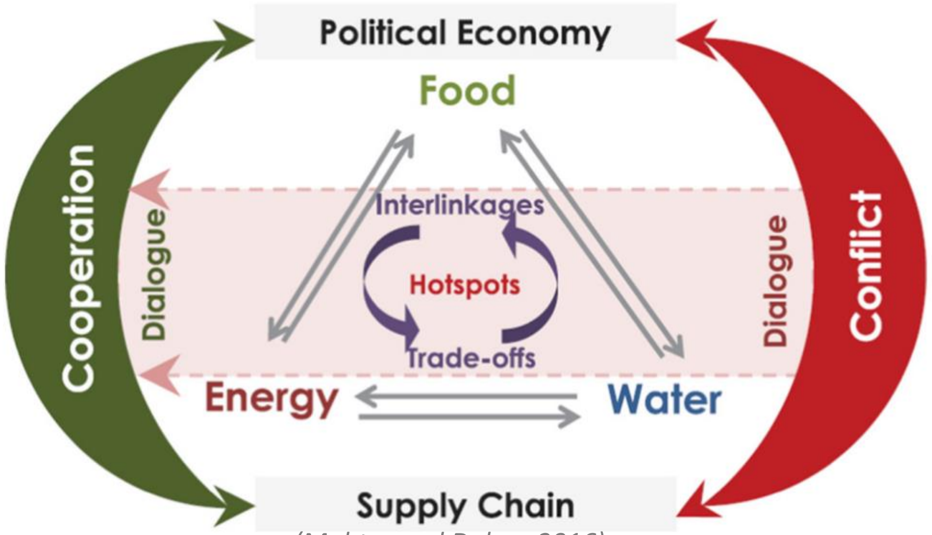
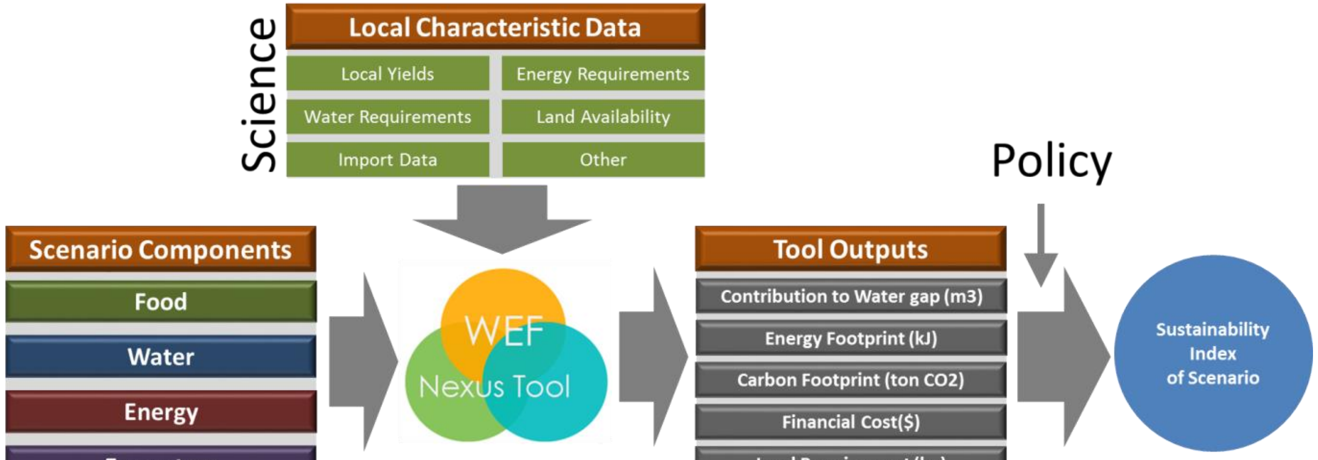
Methods

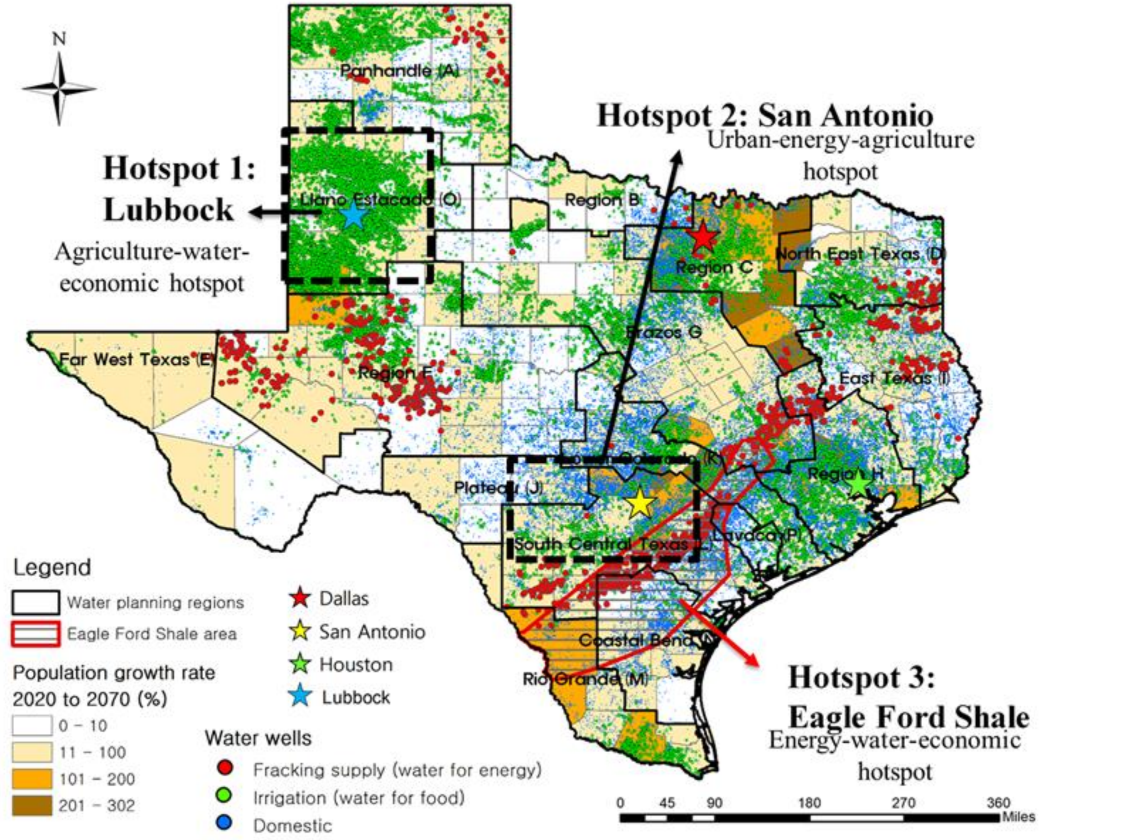


(Mohtar and Daher, 2016)



(Daher and Mohtar, 2015)

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



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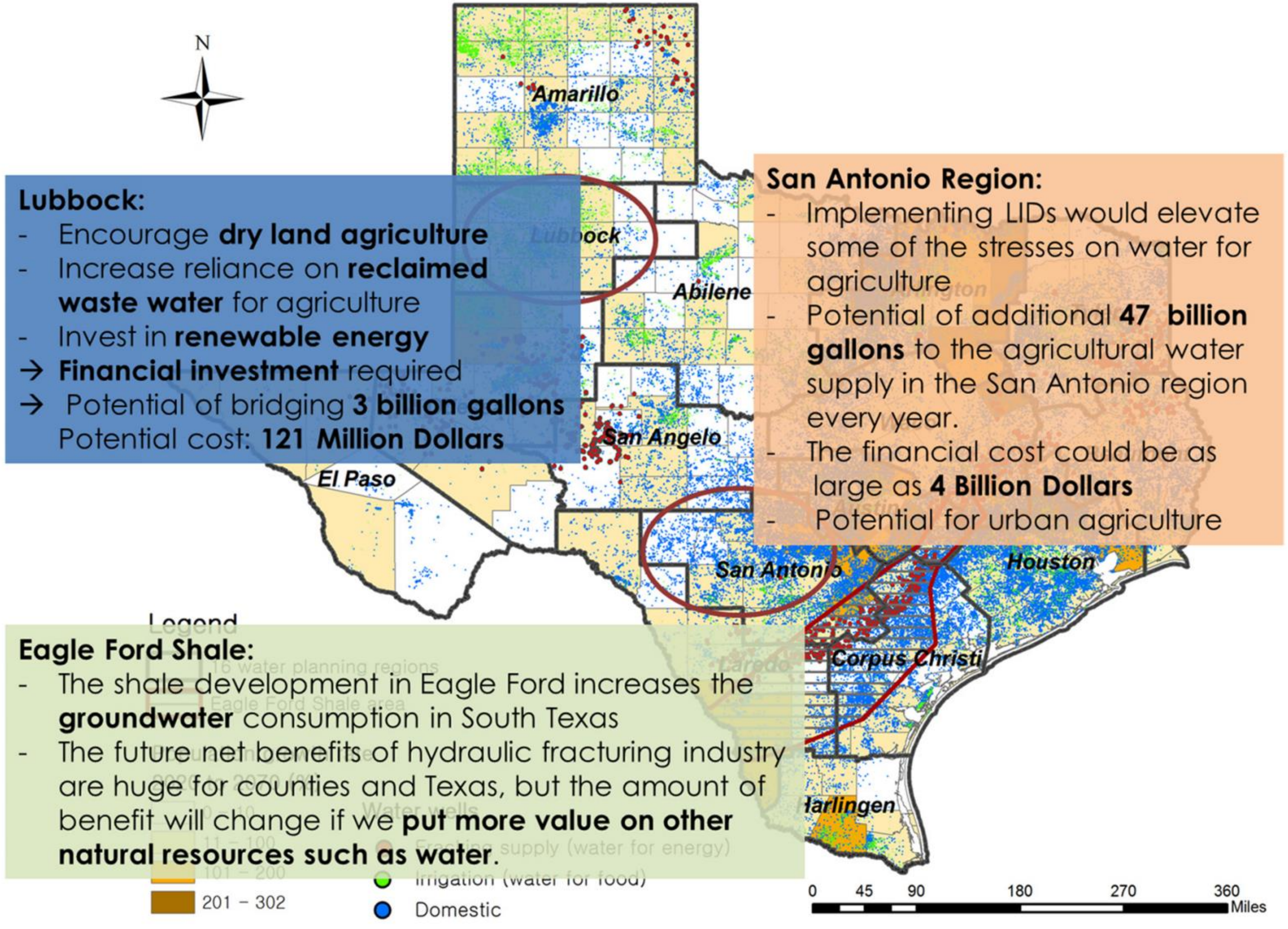
Results



Lubbock:
- Encourage **dry land agriculture**
- Increase reliance on **reclaimed waste water** for agriculture
- Invest in **renewable energy**

→ **Financial investment** required
→ Potential of bridging **3 billion gallons**
Potential cost: **121 Million Dollars**

San Antonio Region:
- Implementing LIDs would elevate some of the stresses on water for agriculture
- Potential of additional **47 billion gallons** to the agricultural water supply in the San Antonio region every year.
- The financial cost could be as large as **4 Billion Dollars**
- Potential for urban agriculture

Eagle Ford Shale:
- The shale development in Eagle Ford increases the **groundwater** consumption in South Texas
- The future net benefits of hydraulic fracturing industry are huge for counties and Texas, but the amount of benefit will change if we **put more value on other natural resources such as water.**

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Key Messages

Bridging the water gap requires:

- **multi-stakeholder** approaches
- **accounting for** the **spatial and temporal distribution** of resources
- **accounting for interconnections** between water and competing resource systems and growing stresses
- **proper communication of trade-offs**
- **financing schemes** and **coherent policies**
- **holistic** yet **localized** solutions

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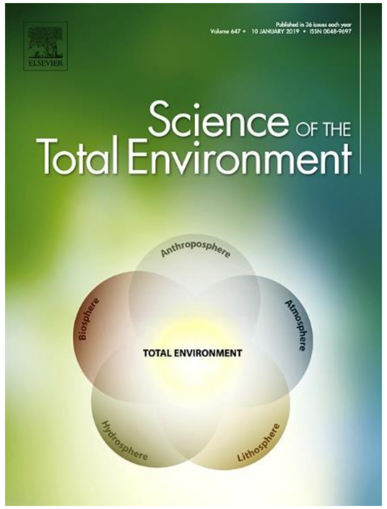

Economic, social, and environmental evaluation of energy development in the Eagle Ford shale

Rabi H. ***Mohtar****, Hamid* ***Shafiezadeh****, John* ***Blake****, Bassel* ***Daher***

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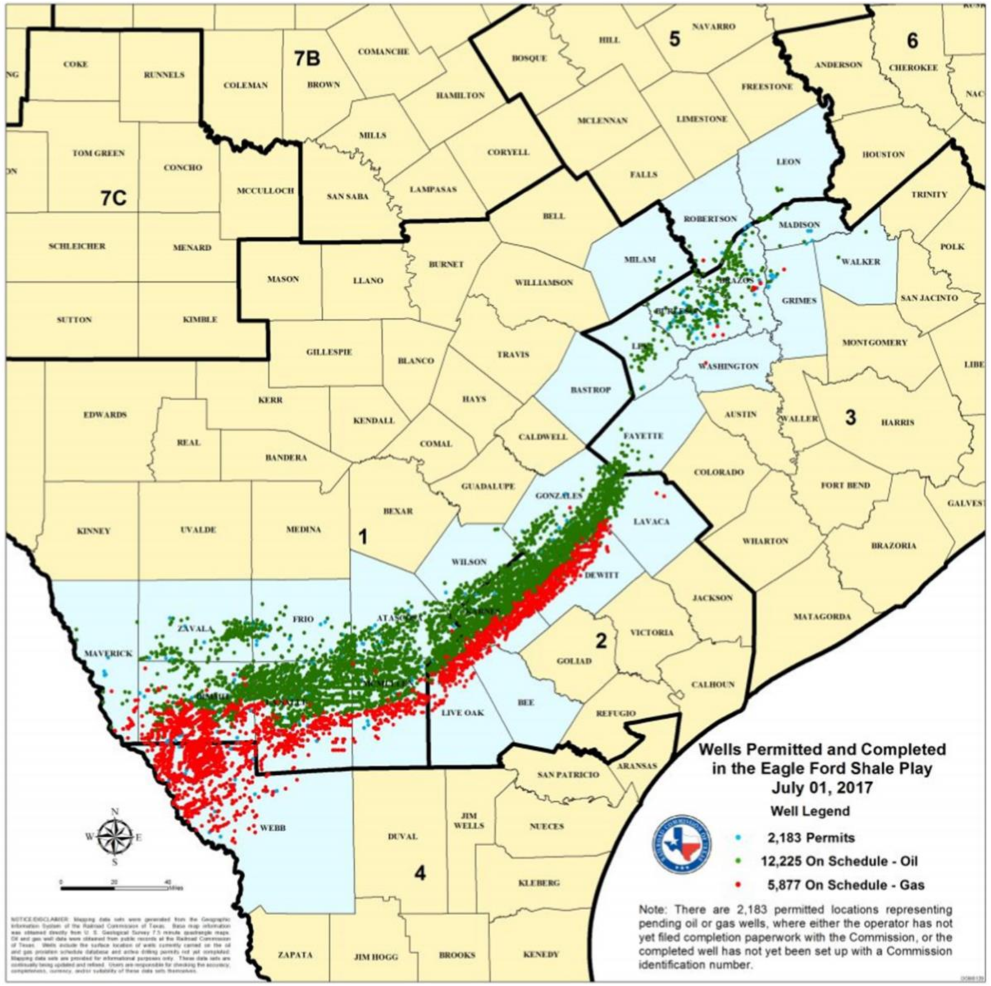
Background and Study Objectives

OBJECTIVES

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;
3) **Develop a framework** for analysis of the economic, societal, and long term sustainability of the sectors;
4) **Develop an assessment tool (WET Tool)** that estimates several economic indicators for different scenarios and their associated trade-offs.



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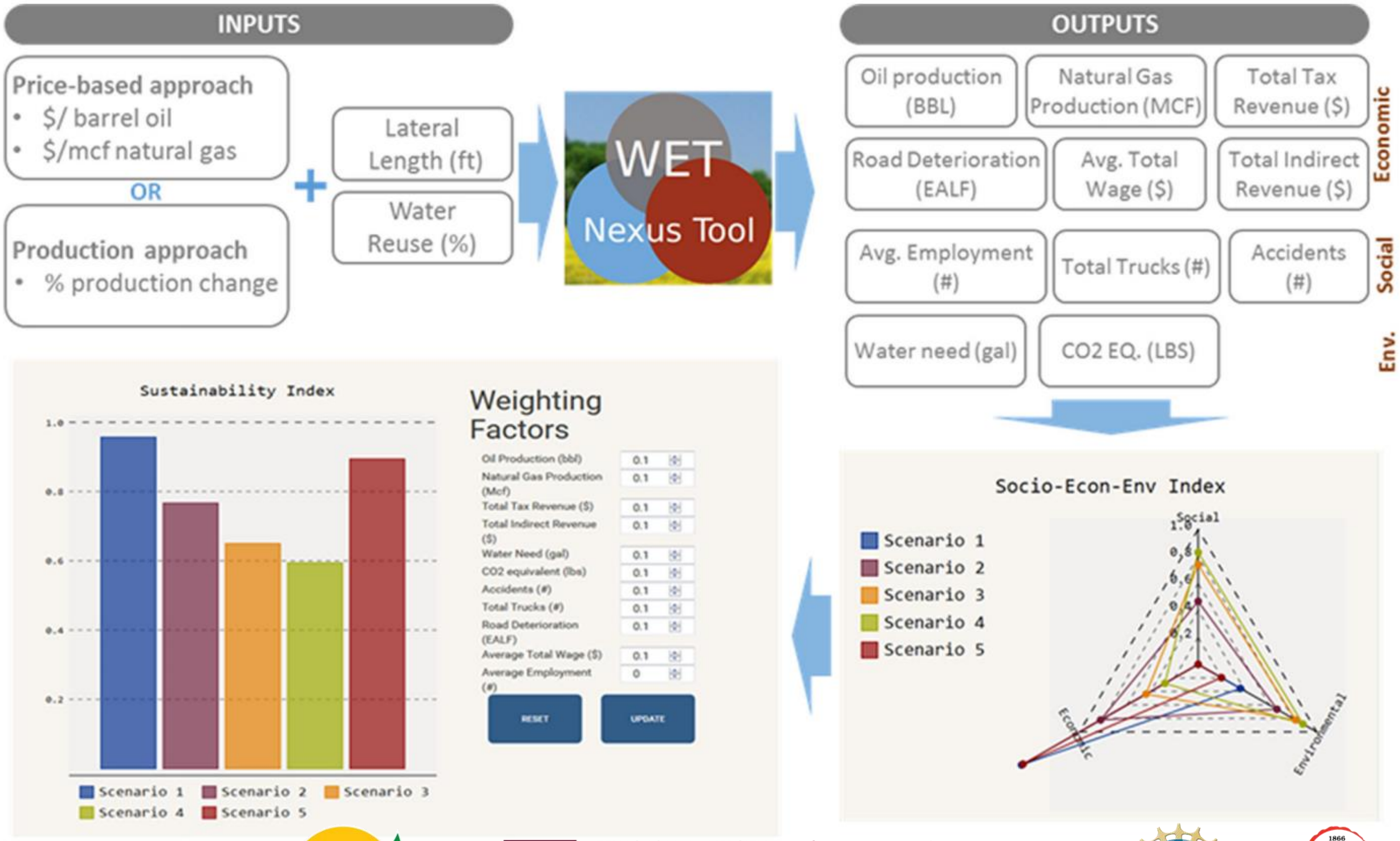
Methods



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Results

Sample scenarios for energy development in the Eagle Ford shale play.

	Oil price	Gas price	Lateral length	Water reuse
Scenario1	$110	$3	5000	10%
Scenario2	$80	$4	5000	10%
Scenario3	$60	$4	6000	15%
Scenario4	$40	$4	6000	15%
Scenario5	$120	$2	7000	20%

- **Price of oil ↓ oil and gas production ↓**
- **Oil production ↑ direct tax revenue for the state ↑**
- **Lateral length ↑ water per fracture ↑**
- **Oil production ↑ employment ↑**
- **Oil production ↑ CO_2 ↑**
- **Oil production ↑** road deterioration ↑

Sample scenarios outputs.

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Oil production (bbl)	1,279,480,431	667,069,963	313,068,713	205,700,802	1,254,145,021
Natural gas production (mcf)	5,828,419	3,038,704	1,426,122	937,029	5,713,008
Total tax revenue ($)	$6,475,482,379	$2,455,729,078	$864,497,484	$378,770,585	$6,923,737,472
Total indirect revenue ($)	$3,136,417,299	$1,635,202,635	$767,431,922	$504,238,704	$3,074,312,076
Water need (gal)	59,853,750,767	31,205,353,643	17,427,305,933	11,450,555,941	80,818,776,904
Co2 equivalent (lbs)	2,087,761,401	1,088,475,358	561,974,726	369,243,707	2,453,530,452
Accidents (#)	792	417	200	134	777
Total trucks (#)	15,145,590	7,896,305	4,076,825	2,678,665	17,799,049
Road deterioration (ealf)	12,979,771	6,767,133	3,493,839	2,295,616	15,253,785
Average total wage ($)	$135,561,848	$90,869,824	$59,705,729	$39,229,459	$132,877,543
Average employment (#)	15,548	10,422	6848	4499	15,240

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Key Messages

1. **Trade-offs** associated with different energy development scenarios.
2. **WET Tool** allows quantification of those trade-offs to facilitate a dialogue among stakeholders.
3. Relations between water, energy, infrastructure, wages, tax revenues, and carbon emissions need to be evaluated.
4. Coherence in policies.

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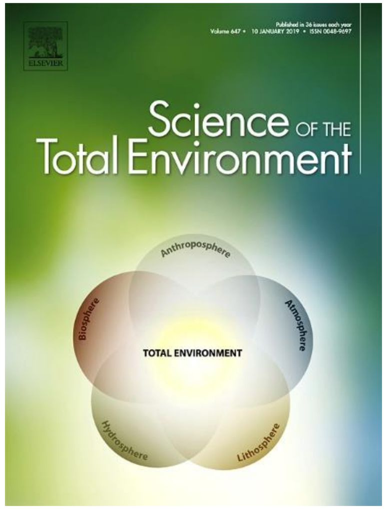


Guiding Water Resources Planning Using the Holistic Water-Energy-Food Nexus Approach: Case of Matagorda County, Texas

Muhammed ***Kulat****, Rabi H.* ***Mohtar****, Francisco* ***Olivera***

Opportunities of the WEF Nexus Approach:

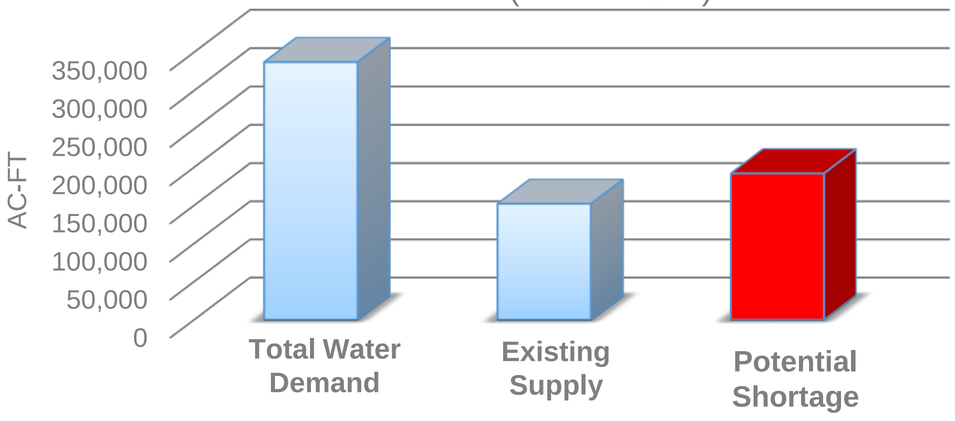
Innovatively driving economic development, social wellbeing, and environmental sustainability

Webinar | 8:30-10:30 AM (CST), 4:30-6:30 PM (Beirut) | Nov 27, 2018

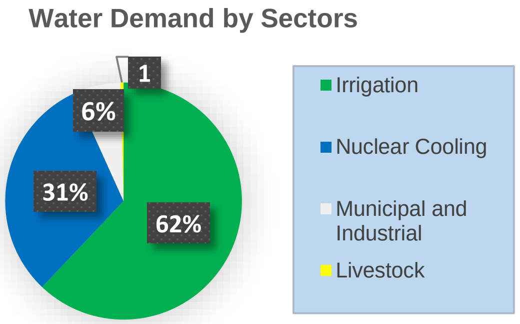
Background and Study Objectives

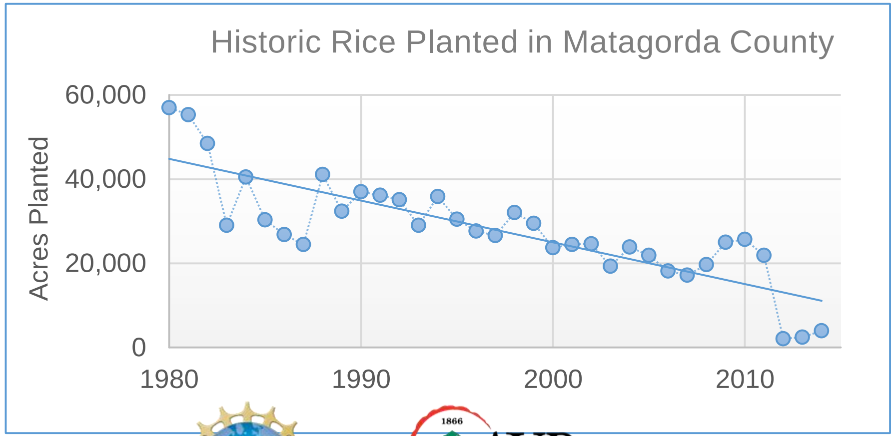
How does a WEF Nexus Approach Play a Role in Water-Related Infrastructure Decisions to Mitigate Water Stresses?

- Objectives:
  - Identify Scenarios
  - Develop a WEF Nexus platform
  - Analyze Sustainability
  - Case Study: Matagorda County, Texas



Agriculture sector suffers





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Methods

IDENTFY SCENARIOS

Resources Interlinkages → **Possible interventions** → **Scenarios**

Food

Water

Energy

Intervention 1

Intervention 2

Intervention 3

Intervention 4

...

Scenario 1

Scenario 2

Scenario 3

Scenario 4

Scenario 5

Scenario 6

...

DEVELOP A WEF NEXUS PLATFORM

Tool Operations → **Outputs of the Tool**

Analytic Tool

Water [m³]

Energy [kWh]

Food Produced [various]

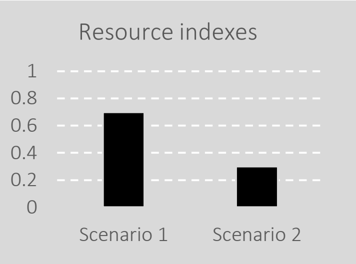
Food Revenue [$]

Costs [$]

CO2 [tons]

ANALYZE SUSTAINABILITY

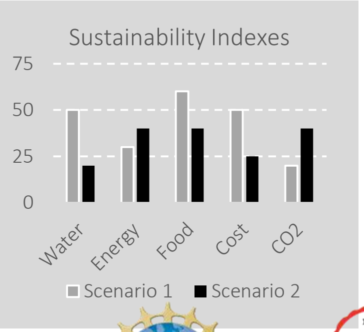
Sustainability Analysis → **Results**



X

Weighting Factors

=



Water-Centric

Energy-Centric

Food-Centric

Cost-Centric

CO2-Centric

All-Equal Optimum

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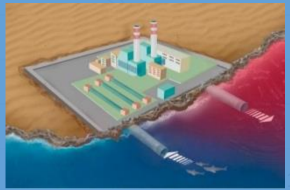
Results

<u>Scenario 9: The Best Scenario</u>

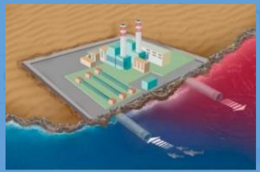
Possible Interventions Included:

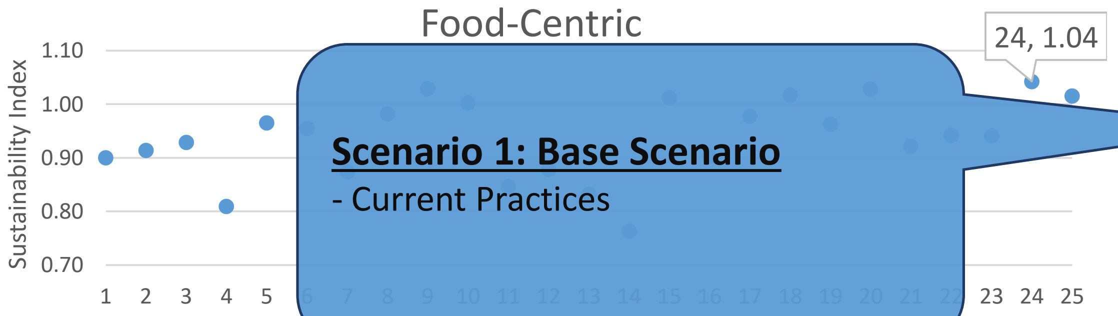
- Conveyance System Improvement
- On-farm Irrigation Improvement
- Building New Reservoir
- Building Desalination for Brackish Water
- Building Water Treatment for Reuse
- Seawater Use for Cooling
- Solar Farm

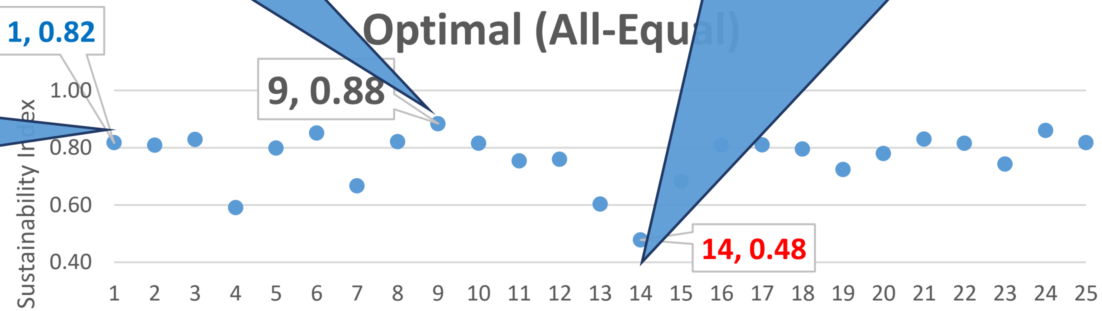


<u>Scenario 14: Worst Scenario</u>

- Cropping Pattern Change (More Water Demanded Crops)
- Conveyance System Improvement
- Building desalination plant for Seawater
- Building desalination plant for Brackish
- Bringing wastewater from Houston
- Seawater use for Cooling







<u>Scenario 1: Base Scenario</u>

- Current Practices

x-axes represent scenarios while y axes are for sustainability indexes

Key Messages

- **The WEF Nexus saves capital**
  - Ag sector, which was suffering, now makes $32 M additional annualy (%1 increase)
- **Water, Energy, and Food Resources are saved**
  - Water demand *reduced* from 460 Mm^3 to 438 Mm^3
  - Energy demand *reduced* (after Solar Contribution): from 60 to 39 M kWh)
  - Food Production *increased*
- **Environment is supported**
  - CO_2 emission reduced (around 20%)
  - Environmental flow requirements and water withdrawal values limited

Output Parameters (Annual)	Presented Scenarios		
	Base Scenario **S-1**	Best Scenario **S-9**	Worst Scenario **S-14**
Water demand (million m^3)	460	438	720
Energy demand after solar (million kwh)	60	39	754
Solar energy produced (million kwh)	0	105	0
CO_2 emission (ton)	12,200	10,100	102,400
Ag. Revenue (million $)	188.0	239.1	270.6
Project costs (million $)	0.2	19 .2	57.8
Irrigated cropland percentage	21%	61%	57%

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Q&A 2

Trade-Off Analysis (20 min)
CST: 8:52 am | Beirut: 4:52 pm

Daher, B., Lee, S., Kaushik, V., Blake, J., Shafiezadeh, H., Askariyeh, M., Zamaripa, S., Mohtar, R.H. (2018). Towards bridging the water gap in Texas: A Water-Energy-Food Nexus Approach. Science of the Total Environment; https://doi.org/10.1016/j.scitotenv.2018.07.398

Mohtar, R. H., Shafiezadeh, H., Blake, J., & Daher, B. (2019). Economic, social, and environmental evaluation of energy development in the Eagle Ford shale play. Science of The Total Environment,646, 1601-1614. doi:10.1016/j.scitotenv.2018.07.202

Kulat, M., Mohtar, R.H., Oliviera, F. (In Review). Guiding Water Resources Planning Using the Holistic Water-Energy-Food Nexus Approach: Case of Matagorda County, Texas

Q/A

Opportunities of the WEF Nexus Approach:
Innovatively driving economic development, social wellbeing, and environmental sustainability

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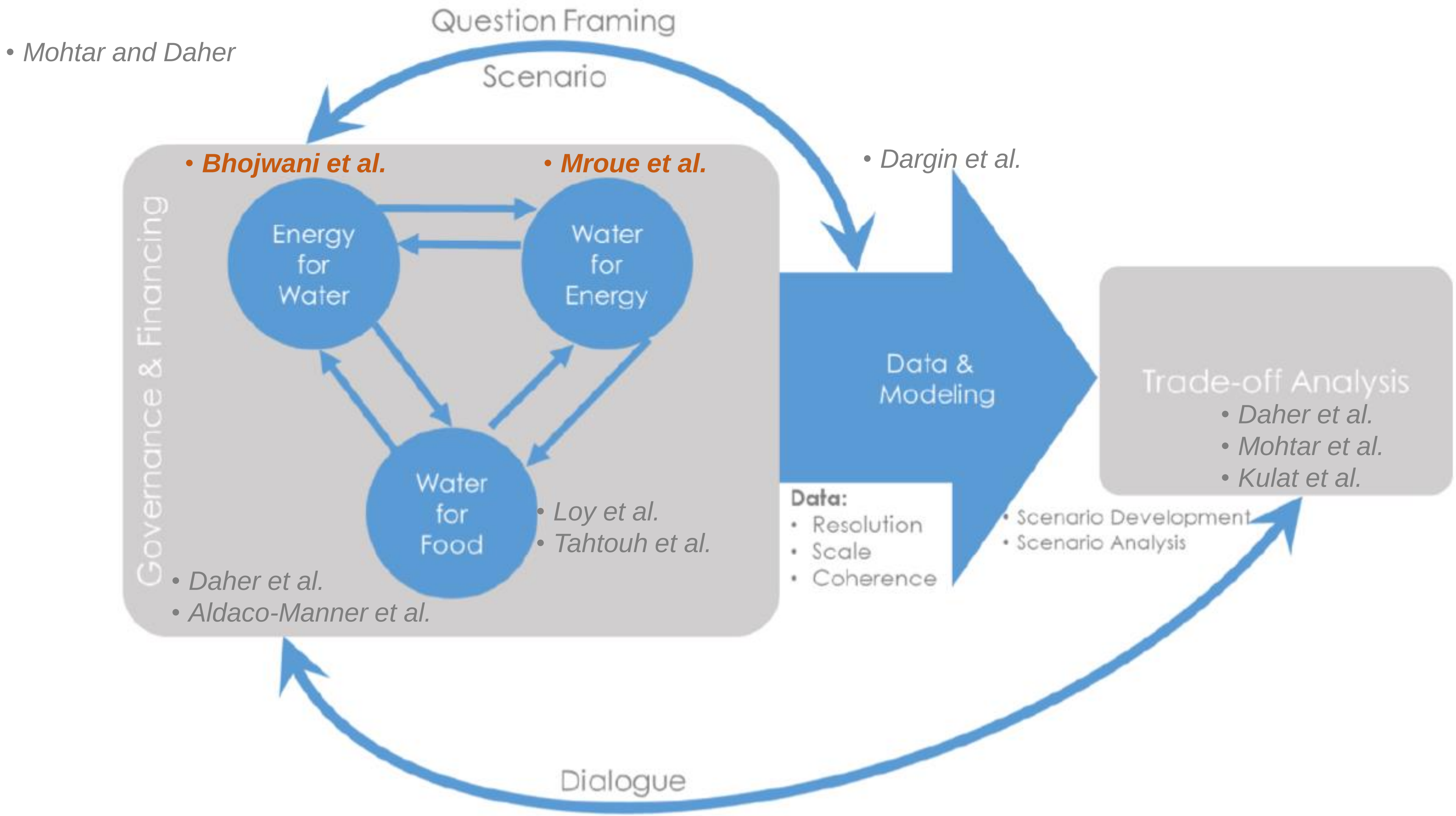

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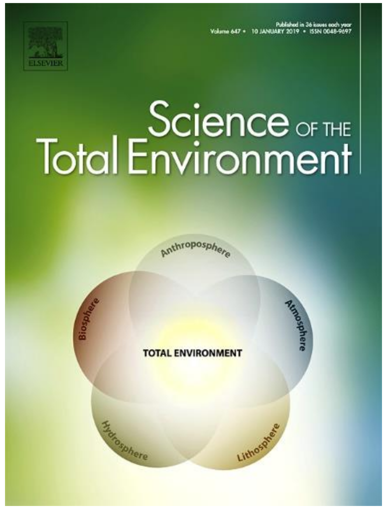


Technology review and data analysis for cost assessment of water treatment systems

*Bhojwani, S., Topolski, K., Mukherjee, R., **Sengupta**, D., El-Halwagi, M.M.*

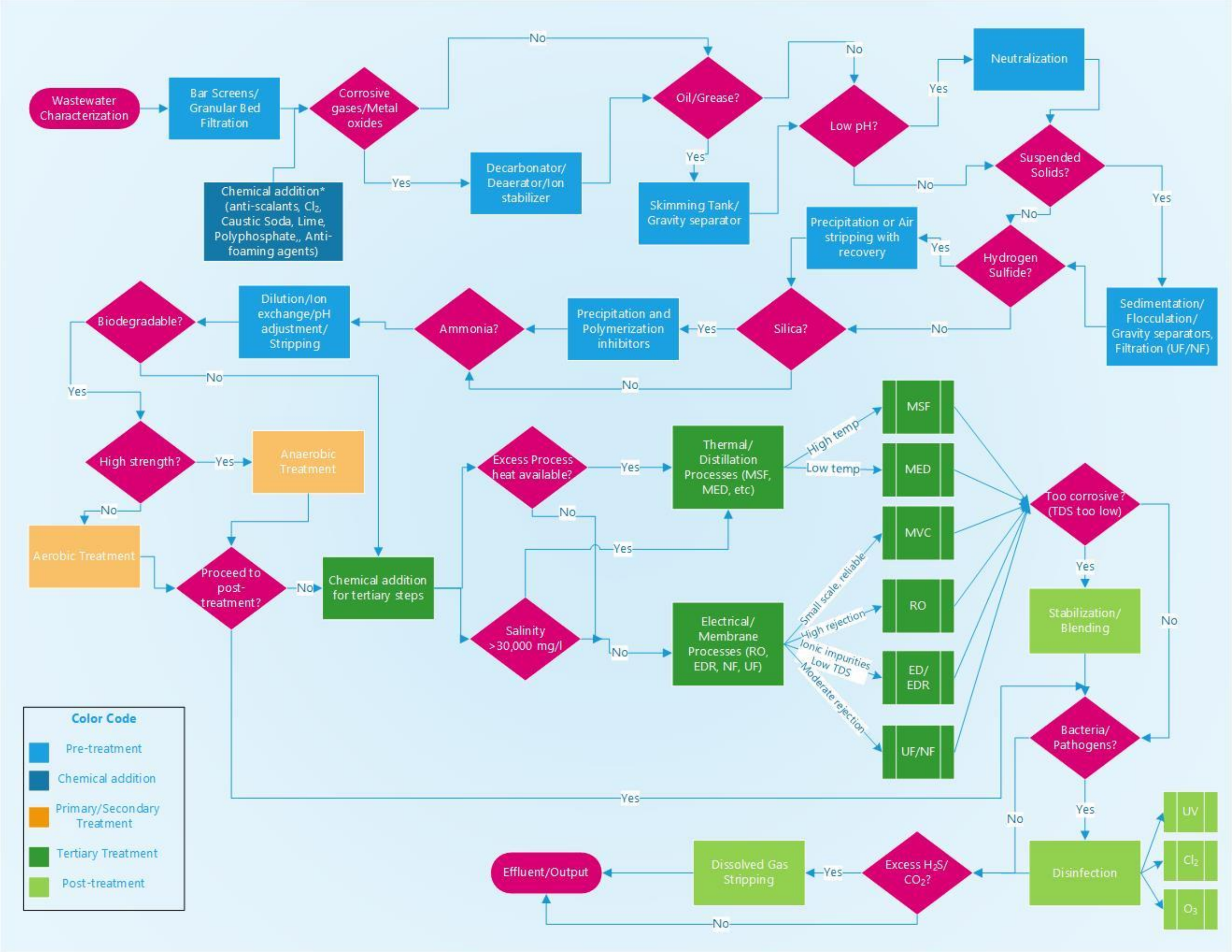
Opportunities of the WEF Nexus Approach:
Innovatively driving economic development, social wellbeing, and environmental sustainability

Webinar | 8:30-10:30 AM (CST), 4:30-6:30 PM (Beirut) | Nov 27, 2018

Background and Study Objectives

- A body of review literature that will aid in the development of water networks that connect the supply chain, reuse, and/or recycle of water systems.
- Capital, operating, and unit product cost comparison for water treatment technologies.
- Cost and other technical data compiled from over 100 research articles, white papers, technical reports.
- Network representation of water distribution and treatment followed by reuse options.
- Brief overview of integration or coupling strategies that can lower cost for treatment.
- Pave the way for formation of optimization frameworks for macroscopic water network systems (cities, regions, etc.).

Methods



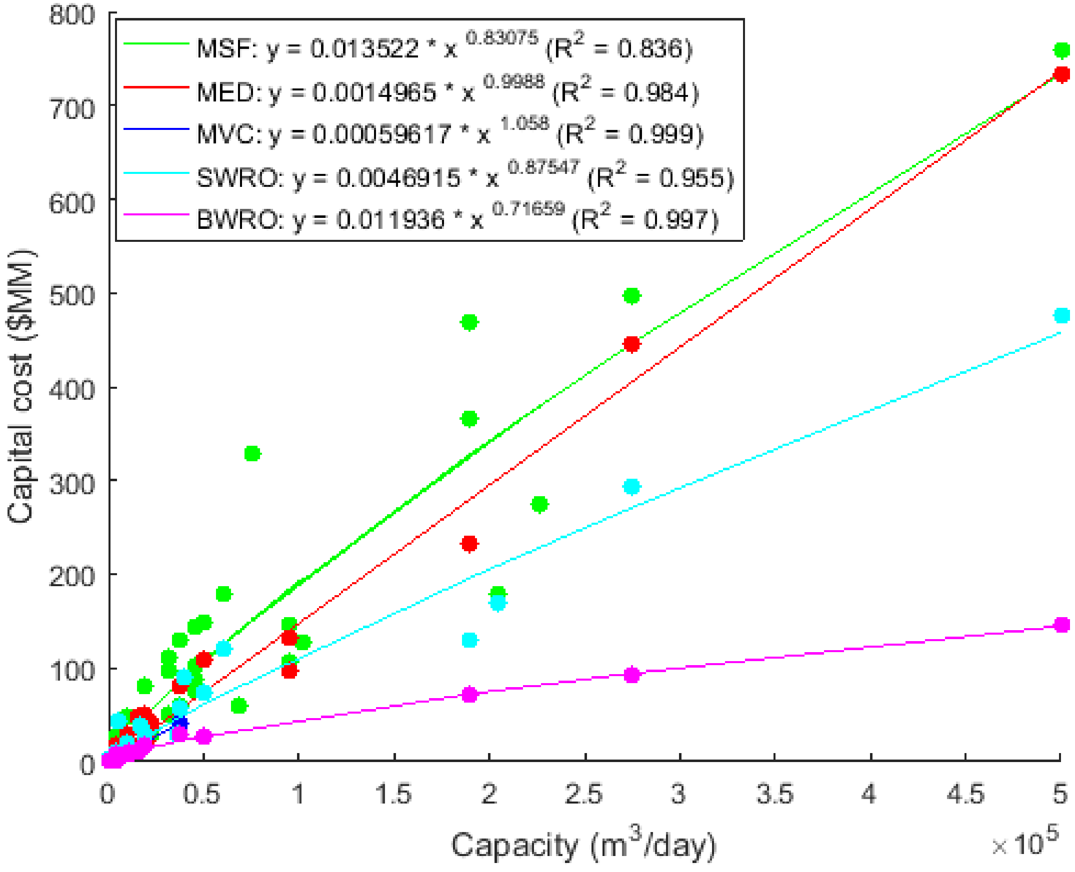
- Flowchart of the decision-making process for the choice of a suitable technology/pathway
- Selection of process depends on:
  - Feed water quality (salinity, hardness, pH, BOD, etc.)
  - Capacity (quantity)
  - Desired product quality
  - Energy availability
  - Site Location
  - Environmental considerations

Methods (contd.)

- Data collection for the different treatment technologies was done for the following:
  - Types: MSF, MED, TMD, TVC, MVC, RO, NF/UF
  - Cost: Capital cost vs Capacity, Operating costs: energy, chemicals, labor, membrane costs (if any), maintenance costs
  - Energy: Unit electricity (kWh/m^3) and thermal energy (MJ/m^3) consumption
  - Performance: Gain Output Ratios (GOR) or Performance Ratio (PR), Plant life, Stages, Unit product cost ($/m3), Conversion factor, Maximum feedstock salinity, Output quality.
- Cost correlations were developed using regression to find relation between capital cost, operating costs and the capacity of the treatment plant.

Results

Capital Cost-Capacity Correlation



Unit Product Cost ($/m3) vs Capacity

Technology	Capacity in m^3/d (mgd)			
	3785 (1)	18,925 (5)	37,850 (10)	189,250 (50)
MSF (PR = 12)	2.746	1.925	1.582	1.339
MED (PR = 12)	2.146	1.455	1.336	1.128
MVC	1.333	0.926	0.867	–
SWRO	1.401	0.893	0.820	0.716
BWRO	0.712	0.447	0.380	0.297

- Detailed breakdown of unit and operating cost heads for each capacity range has been presented in the article
- Membrane techniques more suitable than thermal due to lower cost and energy demands
- Thermal technologies suitable for areas with waste heat availability (dual-purpose plants)

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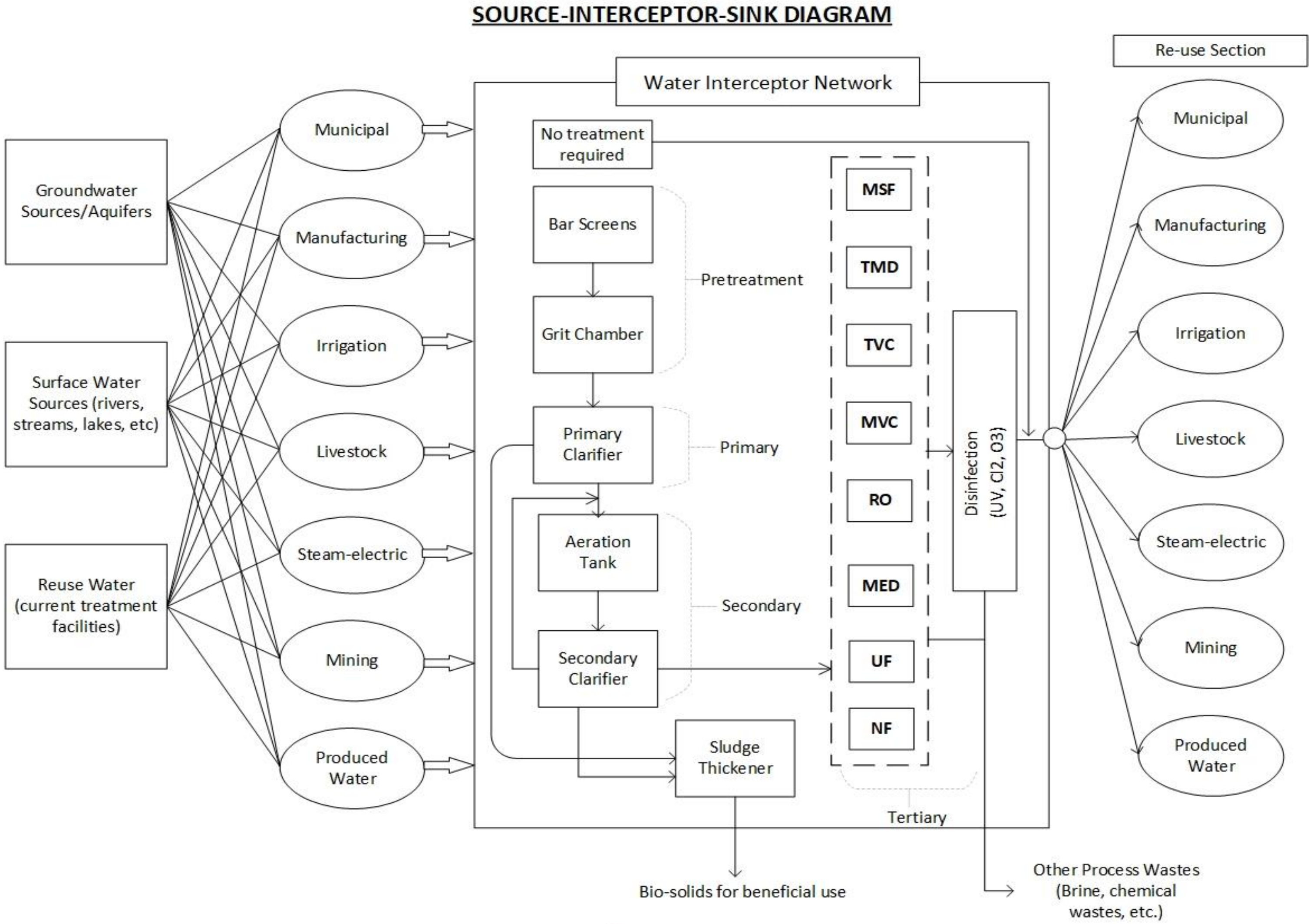
Key Messages



- Water Network Representation
- Generalized framework for water distribution and treatment followed by reuse options
- Selection and sequence of steps within the interceptor network dependent on feed and product quality requirements.
- Conceptual treatment pathway can be any combination of the various processes: optimal choice depends on a set of criteria for cost and/or quality
- The paper provided the data for use in the water network and subsequently has been used to optimize it

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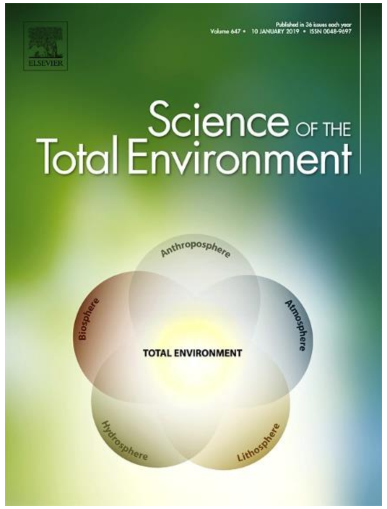


Energy Portfolio Assessment Tool (EPAT): Sustainable Energy Planning Using the WEF Nexus Approach – Texas Case

Ahmed M. ***Mroue****, Rabi H.* ***Mohtar****, Efstratios N.* ***Pistikopoulos****, Mark T.* ***Holtzapple***

Opportunities of the WEF Nexus Approach:

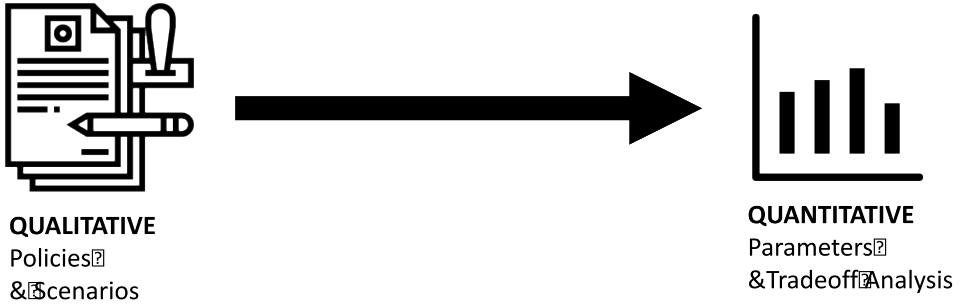
Innovatively driving economic development, social wellbeing, and environmental sustainability

Webinar | 8:30-10:30 AM (CST), 4:30-6:30 PM (Beirut) | Nov 27, 2018

Background and Study Objectives

Background: Technical and Knowledge Gaps

Policy makers can benefit from a nexus scenario-based assessment tool capable of demonstrating the consequent tradeoffs of proposed energy portfolios across the nexus system to ensure sustainable energy development.



Objectives

1. **Develop** a tool (EPAT) to assess the sustainability of energy portfolios through quantification of the tradeoffs between water, environment, land, and energy economics.
2. **Assess** the sustainability and tradeoffs of current and projected energy portfolios of the US Energy Information Administration (EIA) in Texas using EPAT.

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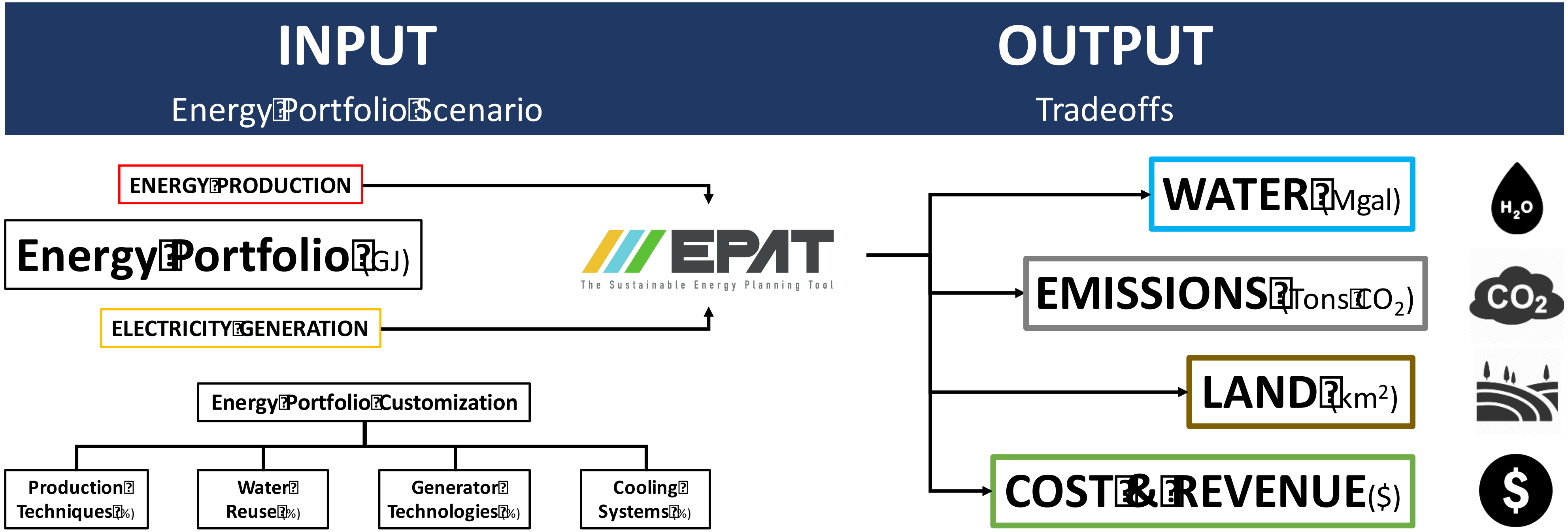
Methods: Energy Portfolio Assessment Tool (EPAT)

The **Energy Portfolio Assessment Tool** (EPAT) is a tool that enables the user to create different energy portfolio scenarios with various energy and electricity sources, and evaluate the scenario's sustainability environmentally and economically.



Results

	Scenario 1: Reference - 2015		**Scenario 2**: CPP & Energy Reference - 2030		**Scenario 3**: No CPP & Energy Reference - 2030	
Energy Production	165 Billion Gal	Water Consumption	6%	Water Consumption	13%	Water Consumption
	400 Million Tons	Carbon Emissions	35%	Carbon Emissions	35%	Carbon Emissions
	5,883 km^2	Land Use	4.5%	Land Use	4.5%	Land Use
	83,218 Million USD	Revenue	3%	Revenue	3%	Revenue
Electricity Generation	105 Billion Gal	Water Consumption	5%	Water Consumption	16%	Water Consumption
	3,678 Billion Gal	Water Withdrawal	35%	Water Withdrawal	12.5%	Water Withdrawal
	179 Million Tons	Carbon Emissions	0%	Carbon Emissions	20%	Carbon Emissions
	85 km^2	Land Use	143%	Land Use	58%	Land Use
	1,745 Million USD	Cost	18%	Cost	18%	Cost

GREEEN **Positive Impact**
RED **Negative Impact**

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Key Messages

1. Decision makers need a holistic framework that draws the links between energy and other systems, and quantifies impact tradeoffs across the nexus system.

2. EPAT is a tool that enables the policy maker to create different energy portfolio scenarios using various energy and electricity sources, and then to evaluate the scenario’s sustainability tradeoffs, both environmentally and economically.

3. Conservation policies (i.e. CPP) have tradeoffs that contradict sustainability guidelines: these should be evaluated prior to execution.

4. Sustainable energy development requires moving beyond the silo, to a nexus mentality.

Q&A 3

Water And Energy (15 min)

CST: 9:12 am | Beirut: 5:12 pm

Bhojwani, S., Topolski, K., Mukherjee, R., Sengupta, D., El-Halwagi, M.M. (In Review). Technology review and data analysis for cost assessment of water treatment systems. Science of the Total Environment Elsevier.

Mroue, A. M., Mohtar, R. H., Pistikopoulos, E. N., & Holtzapple, M. T. (2019). Energy Portfolio Assessment Tool (EPAT): Sustainable energy planning using the WEF nexus approach – Texas case. Science of the Total Environment, 648, 1649-1664. doi:10.1016/j.scitotenv.2018.08.135

Q/A

Opportunities of the WEF Nexus Approach:
Innovatively driving economic development, social wellbeing, and environmental sustainability

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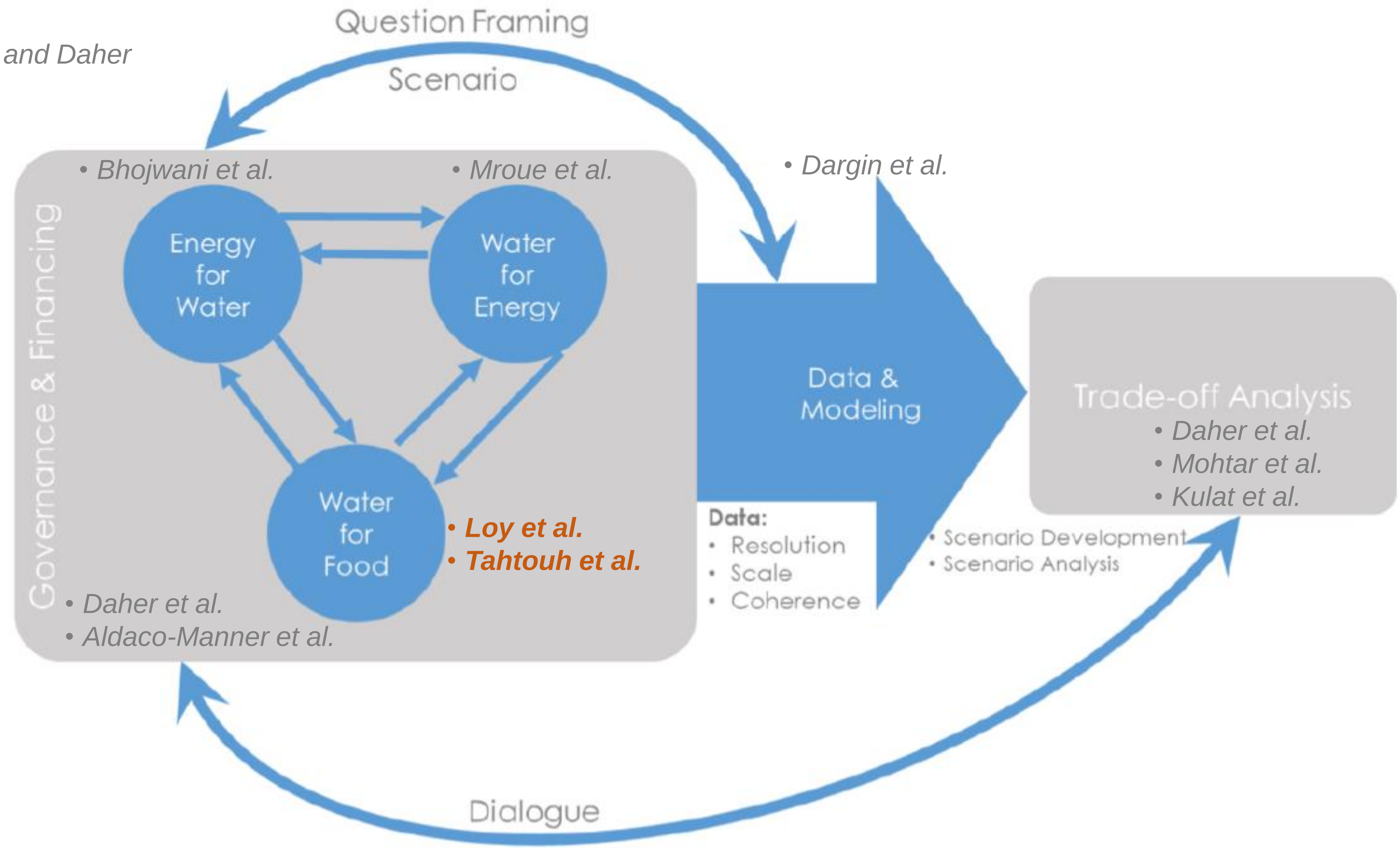
- *Mohtar and Daher*



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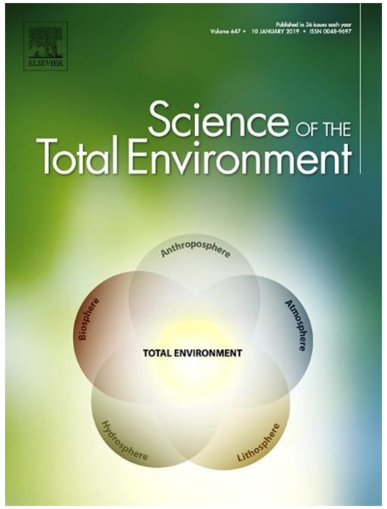

The Effect of Municipal Treated Wastewater on the Water Holding Properties of a Clayey, Calcareous Soil

*Sonja **Loy Cook**, Amjad T. **Assi**, Rabi H. **Mohtar**, Cristine **Morgan**, Anish **Jantrania***

Opportunities of the WEF Nexus Approach:

Innovatively driving economic development, social wellbeing, and environmental sustainability

Webinar | 8:30-10:30 AM (CST), 4:30-6:30 PM (Beirut) | Nov 27, 2018

Background and Study Objectives

Objectives:

(1) Quantify the impacts of secondary treated wastewater and brackish groundwater on the soil water holding properties of a clayey, calcareous soil.

(2) Evaluate and compare the field-scale impacts of irrigating with secondary treated wastewater and brackish groundwater on irrigation management and overall water use in this region.

Soil Properties:

- High clay content (30-50%)
- Limestone derived
- Disk harrow tillage
- Drip irrigation

Wastewater treatment:

- Secondary Treatment
  - BOD ~ 20 mg/l
- Water Canals to Farms
- On-farm Disk Filtration

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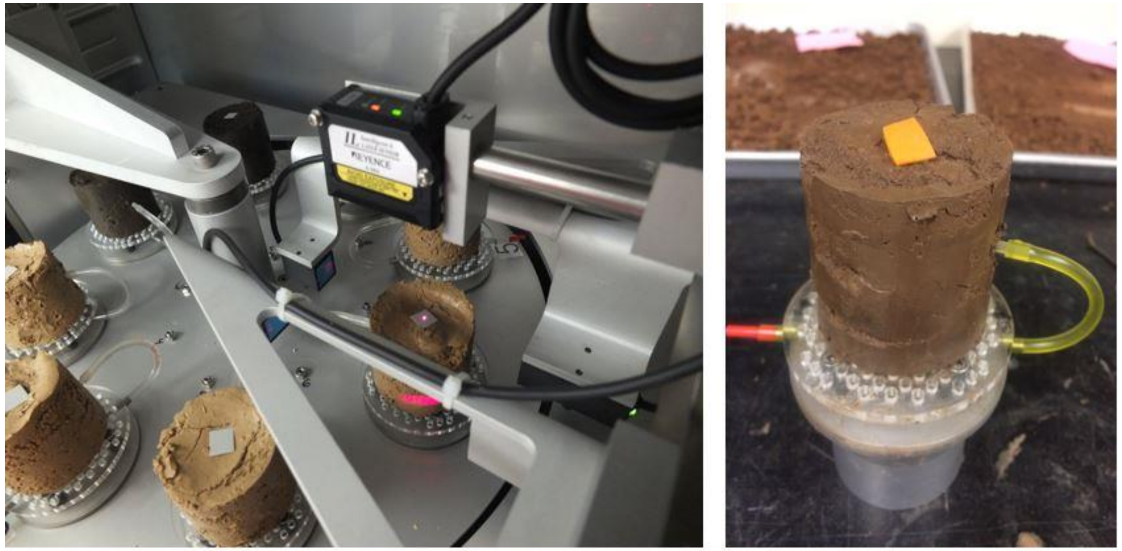
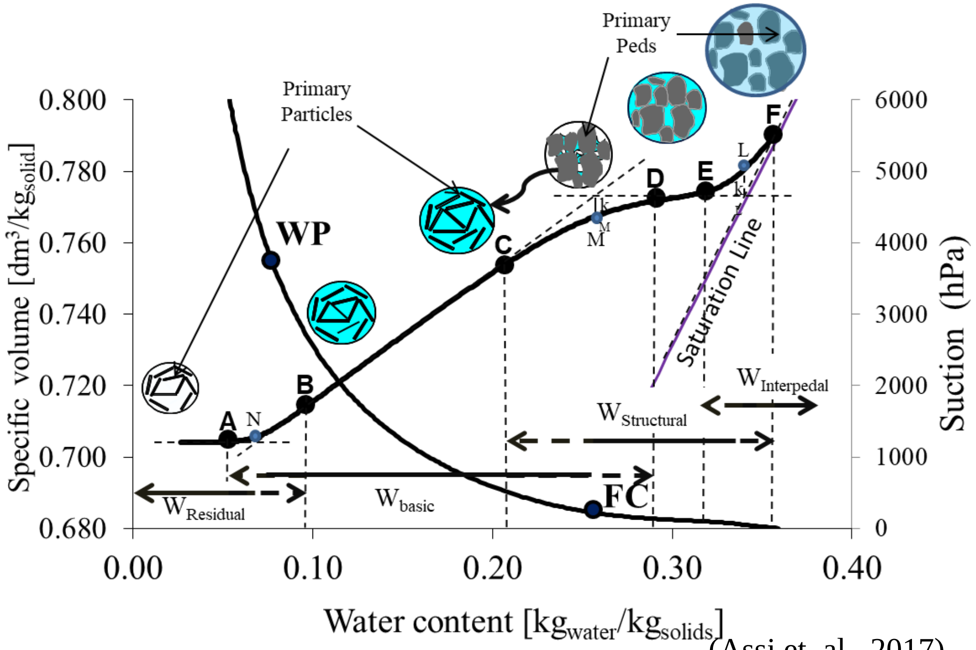
Methods: TypoSoil^{TM}



(a) (b)

(a) Inside the TypoSoil^{TM} Device (TypoSoil^{TM} User Manual),
(b) Standard soil core (φ =5cm, h=5cm ~ 100cm^3)



(Assi et. al., 2017)

- **Field Capacity** (FC): contribution of the water loss is mainly from the micropore space (no more flux out of the soil horizon, most of macropore water is drawn out) between points D and C.
- **Permanent Wilting Point** (PWP): when air entry occurs between the clay particles (between points A and B)
- **Available Water Capacity** (AW): difference between FC and PWP

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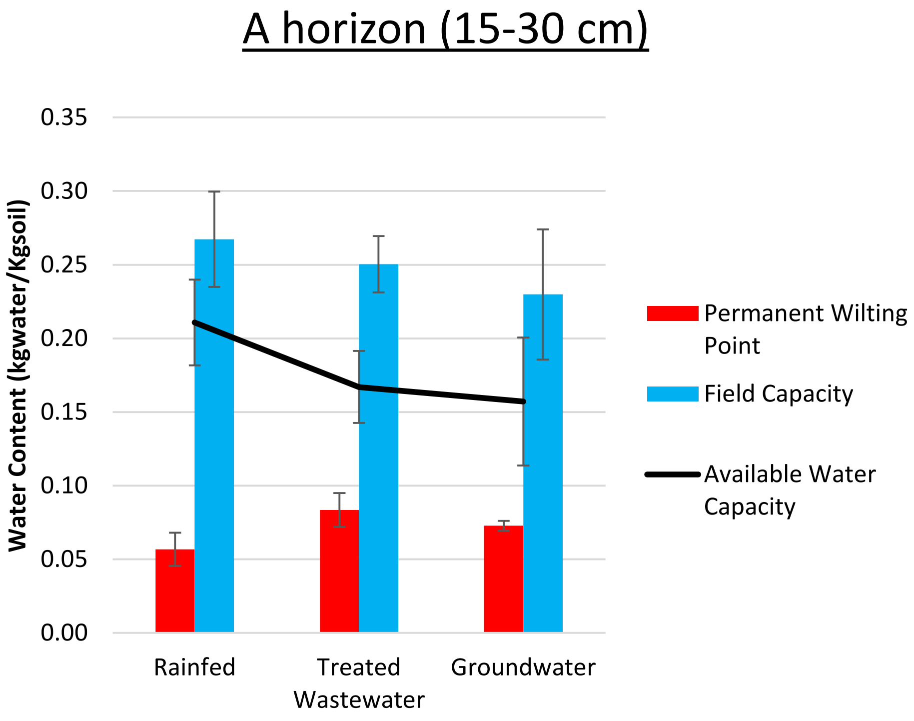
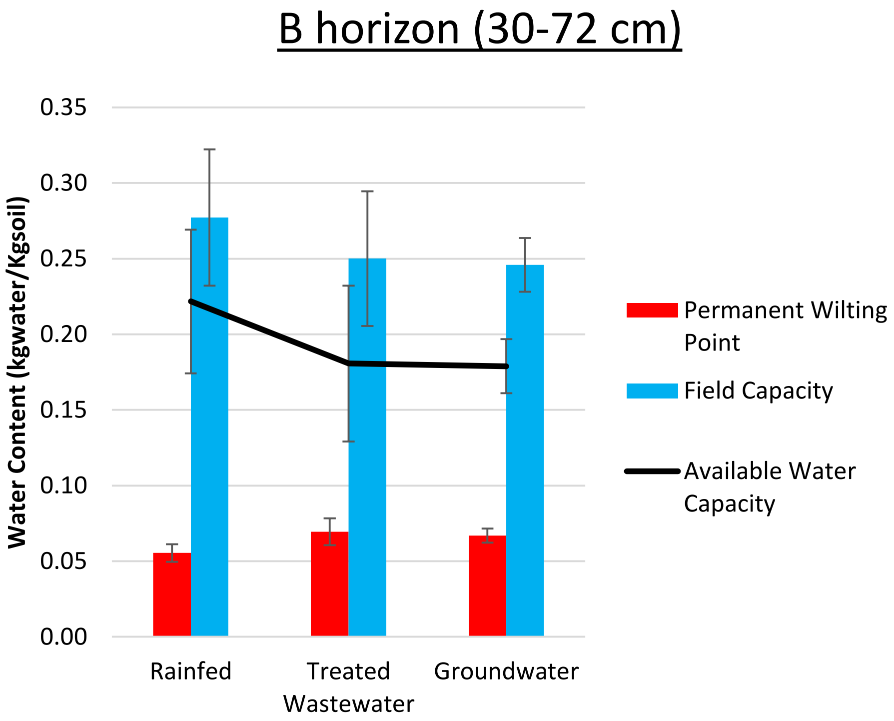
Results





*Note: Variability of numbers was found to be from the field by a comparison of SD between localized sample group SD and overall SD

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Key Messages

- Using TWW for irrigation does degrade soil water holding ability (compared to rain-fed soil).

- TWW irrigation is no worse than using brackish groundwater, so it can be considered a suitable alternative for irrigation *in this case*!

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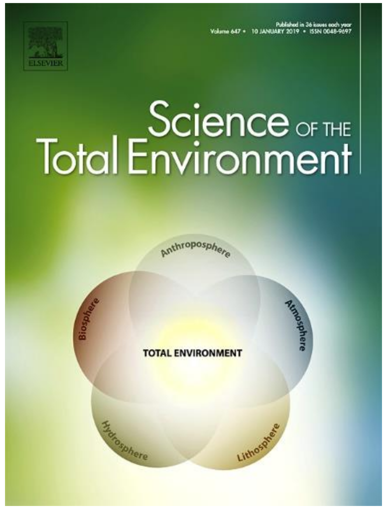


Impact of Brackish Groundwater and Treated Wastewater on Soil Chemical and Mineralogical Properties

*Jeffry **Tahtouh**, Rabi H. **Mohtar**, Amjad T. **Assi**, Paul **Schwab**, Anish **Jantrania**, Youjun **Deng**, Clyde **Munster***

Opportunities of the WEF Nexus Approach:
Innovatively driving economic development, social wellbeing, and environmental sustainability

Webinar | 8:30-10:30 AM (CST), 4:30-6:30 PM (Beirut) | Nov 27, 2018

Background and Study Objectives

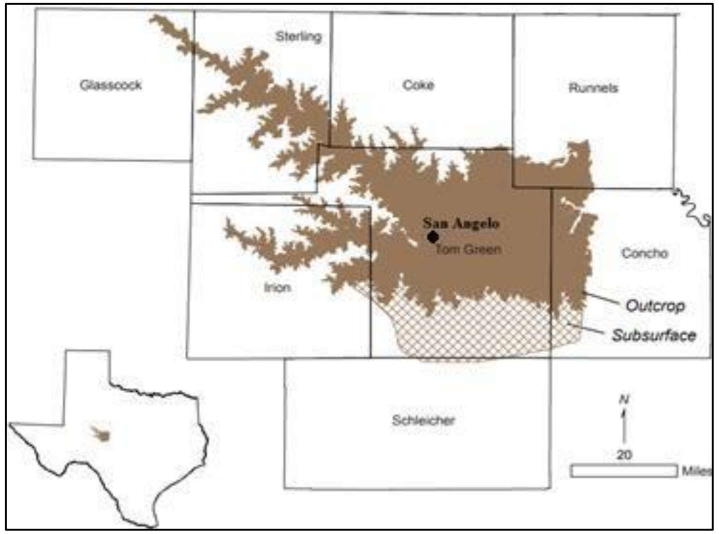
<u>The use of alternative water sources is a powerful solution for the water shortage, however:</u>

<u>when allocating 'New' water for agriculture purposes,</u>

<u>*Decision-makers need to be aware of the long term impact on soil health.*</u>

Profile of an Angelo Clay Loam

Groundwater Source: Lipan Aquifer



Treated Wastewater Source: Canal holding treated wastewater

Treated Wastewater Source: Water Reclamation Facility San Angelo

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Methods: Water & Soil Analyses

Water

The water analysis was performed at Texas A&M University Soil, Water, and Forage Laboratory:

- ✓ **ICP** - Na, Ca, Mg, K, SO_4, B, P
- ✓ **Titration** - CO_3, HCO_3, Cl^-
- ✓ **Calculated** - TDS, Alkalinity, Hardness, SAR
- ✓ **ISE** – pH
- ✓ **Conductivity**- EC
- ✓ **Cd-red** - $N\text{-}NO_3$

Treated wastewater sampling

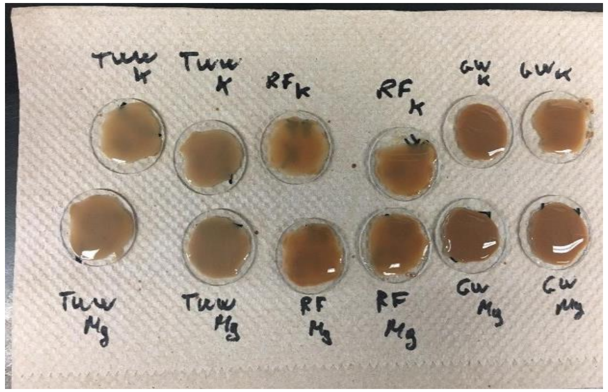
Soil

Top **three soil horizons** (Ap, A, and B) were sampled from three locations (one per experimental group)

The **physicochemical and mineralogical** parameters of the soils were analyzed in Heep Center at TAMU:

- ✓ **Hydrometer** - Texture/PSD
- ✓ **K saturation** – CEC
- ✓ **NH4OAc extraction**-Exchangeable Cations
- ✓ **Calculated** - ESP, ESR, SAR
- ✓ **Acid neutralization** – Inorganic Carbon
- ✓ **Loss on ignition** – Organic Carbon
- ✓ **Saturated paste** – EC, pH, Soluble Cations
- ✓ **XRD and K-Quantification** – Clay Mineralogy

Soil clay mineralogy treatments



Saturated paste method

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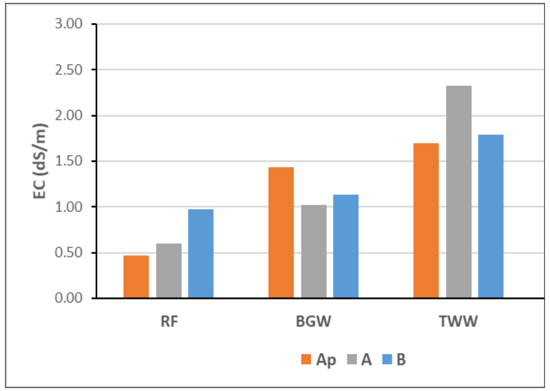
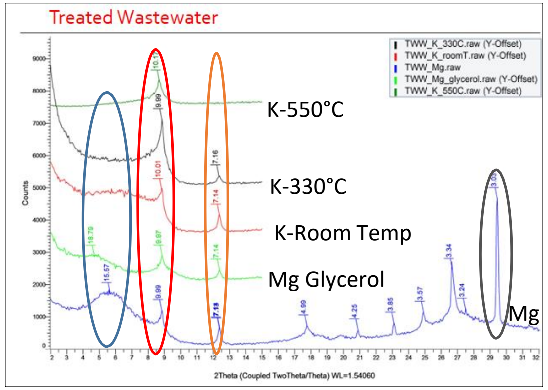
Results

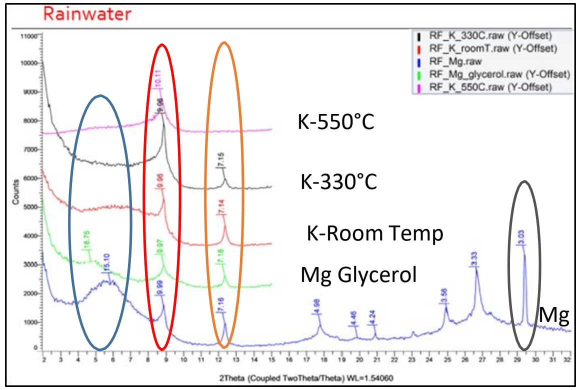
Water

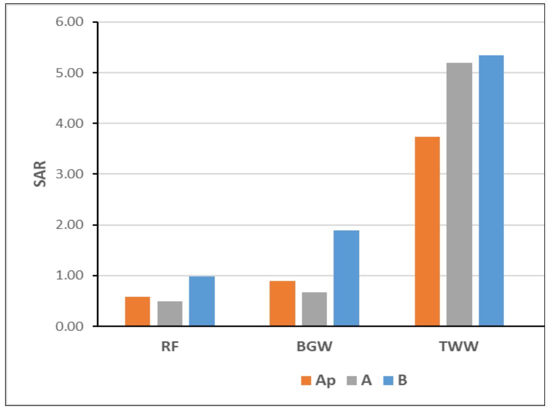
Chemical ← **Soil** → **Mineralogical**

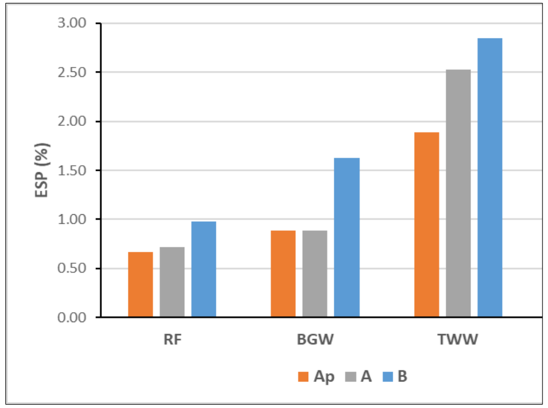
Parameters	TWW	BGW	Irrigation Water Quality Criteria (FAO, 1985)
pH	7.7	7.09	**6.5-8.5**
EC(dS/m)	2.135	**7.02**	**3**
SAR	4.7	4.2	**12-20**
Calcium (ppm)	101	**739**	**400**
Magnesium (ppm)	49	**200**	**60**
Sodium (ppm)	229	495	**920**
Potassium (ppm)	25	8	**2**
Boron (ppm)	0.49	0.365	**3**
Bicarbonate (ppm)	295	215	**610**
Sulfate (ppm)	212	**1280**	**960**
Chloride (ppm)	431	**1339**	**355**
Nitrate-N (ppm)	11.06	34.61	**40**
Phosphorus (ppm)	2.5	0.07	**5**
Total Dissolved Salts (ppm)	1356	**4312**	**2000**

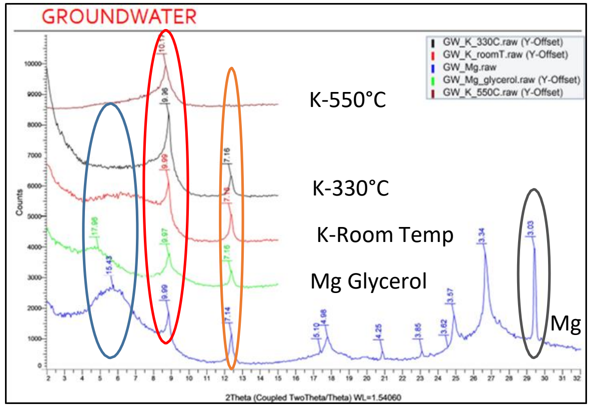












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Key Messages

- Unconventional water sources, treated wastewater (TWW) and brackish groundwater (BGW), are viable substitutes for freshwater irrigation in semi-arid and arid regions (when the right conditions exist).

- Clay mineralogy, in this soil type, is fairly stable and plays a major role in the fertility of the soil

- TWW is the more suitable alternative, compared to BGW, because it has a better quality and decreases the pressure on the aquifer (for this case)

Q&A 4

Water And Food (15 min)

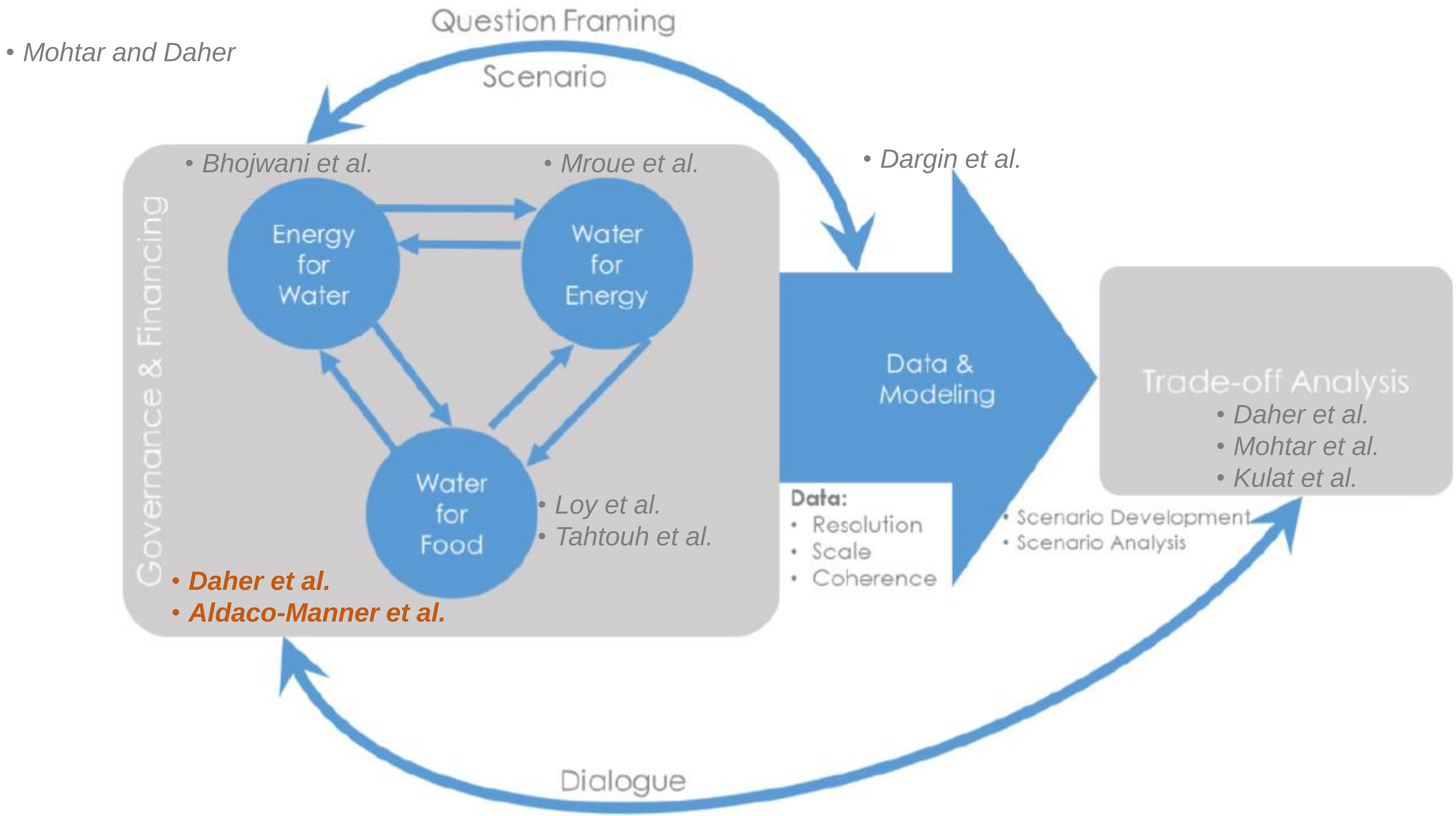
CST: 9:27 am | Beirut: 5:27 pm

Loy, S., Assi, A. T., Mohtar, R. H., Morgan, C., & Jantrania, A. (2018). The effect of municipal treated wastewater on the water holding properties of a clayey, calcareous soil. Science of the Total Environment, 643, 807-818. doi:10.1016/j.scitotenv.2018.06.104

Tahtouh, J., Mohtar, R., Assi, A., Schwab, P., Jantrania, A., Deng, Y., & Munster, C. (2019). Impact of brackish groundwater and treated wastewater on soil chemical and mineralogical properties. Science of The Total Environment, 647, 99-109. doi:10.1016/j.scitotenv.2018.07.200

Q/A

Opportunities of the WEF Nexus Approach:
Innovatively driving economic development, social wellbeing, and environmental sustainability



Question Framing
Scenario
• Mohtar and Daher
• Bhojwani et al.
• Mroue et al.
• Dargin et al.
Governance & Financing
Energy for Water
Water for Energy
Water for Food
• Loy et al.
• Tahtouh et al.
• Daher et al.
• Aldaco-Manner et al.
Data & Modeling
Data:
• Resolution
• Scale
• Coherence
• Scenario Development
• Scenario Analysis
Trade-off Analysis
• Daher et al.
• Mohtar et al.
• Kulat et al.
Dialogue

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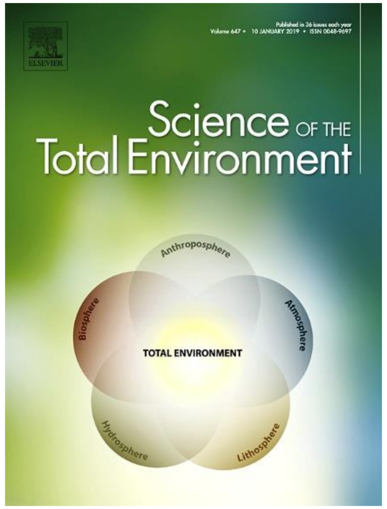


Analysis of four governance factors on efforts of water governing agencies to increase water reuse in the San Antonio, Region

*Lindsey **Aldaco-Manner**, Rabi **Mohtar**, Kent **Portney***

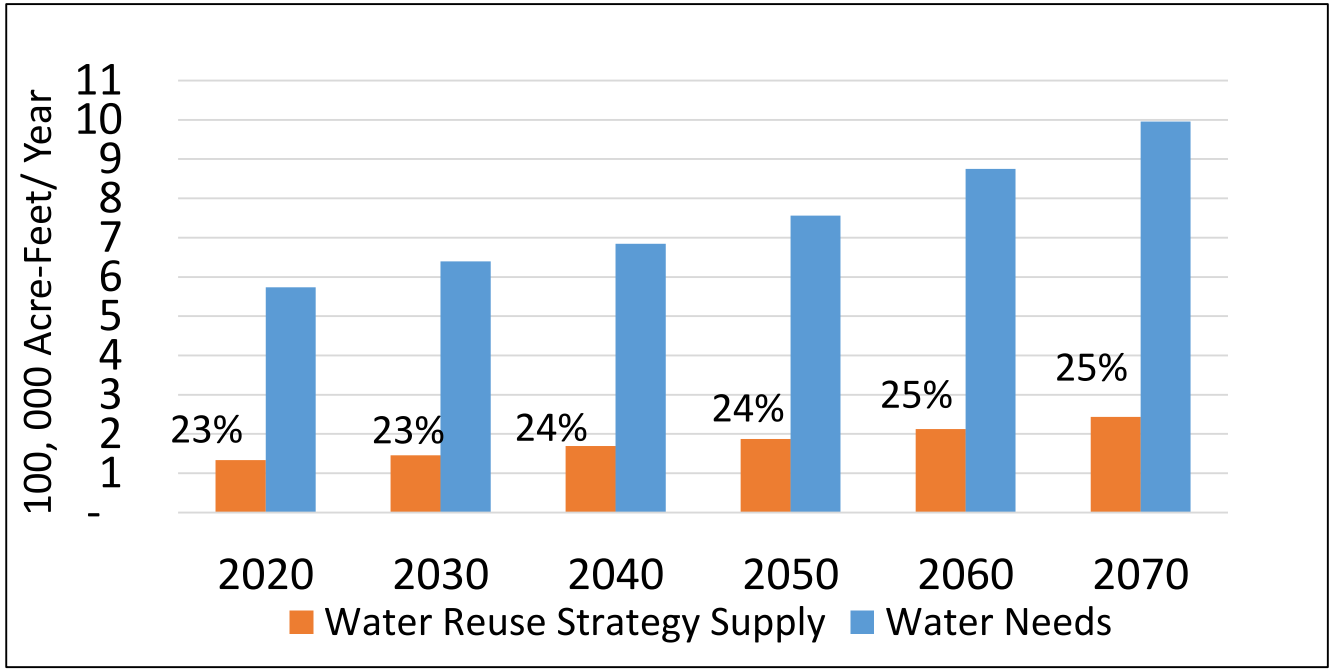
Opportunities of the WEF Nexus Approach:

Innovatively driving economic development, social wellbeing, and environmental sustainability

Webinar | 8:30-10:30 AM (CST), 4:30-6:30 PM (Beirut) | Nov 27, 2018

Background and Study Objectives

Projected Annual **Water Reuse Strategy Supplies** and **Water Needs** for the San Antonio Region

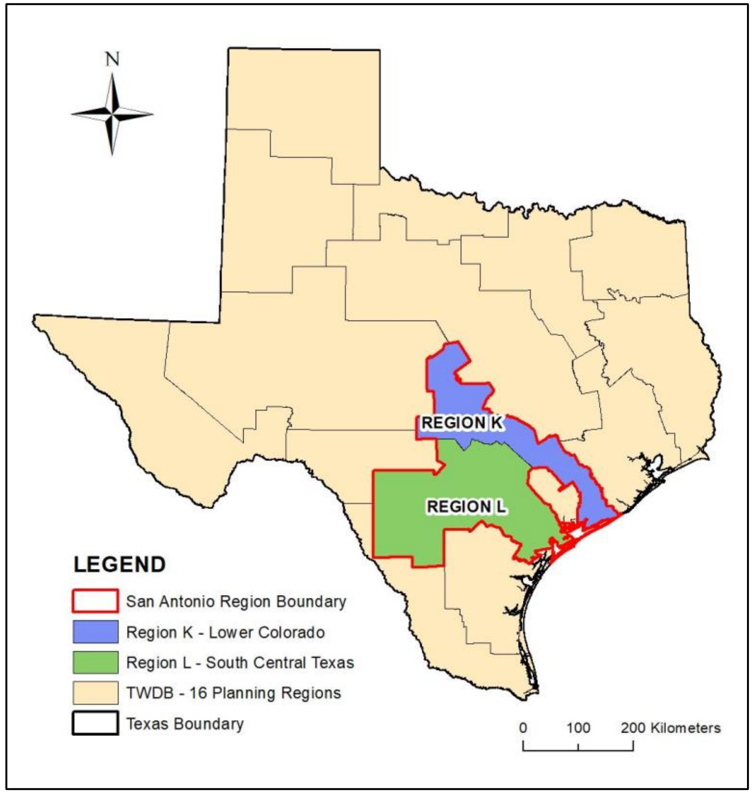


OBJECTIVES

1. Identify and analyze the types and scales of agencies central to contributing to water reuse in the San Antonio Region.

2. Determine if agencies are working to increase water reuse in the San Antonio Region.

Methods



Define Boundary → Develop a Data Base of Agency Personnel → Develop Survey

↓

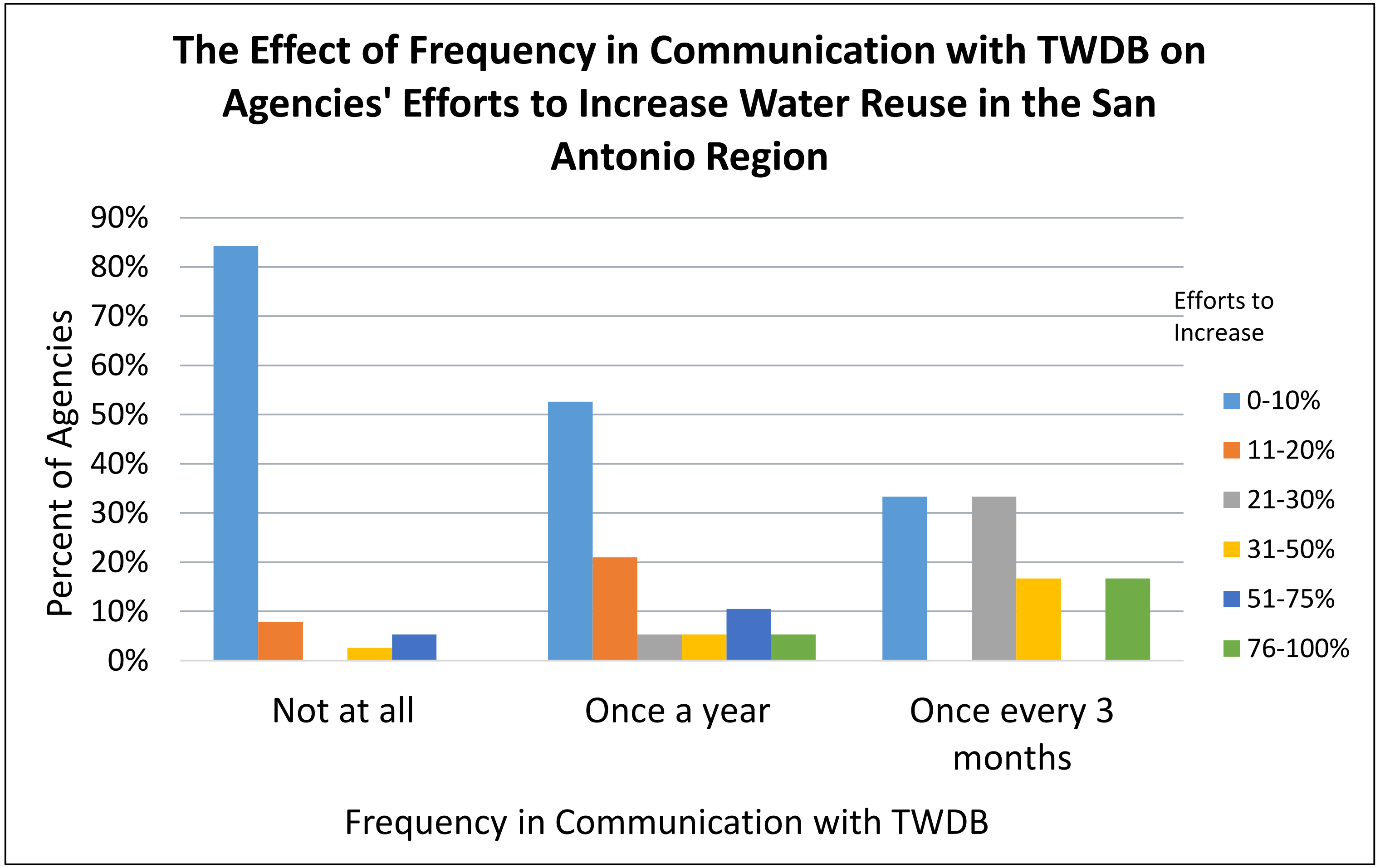
Send Survey Via Mail (Qualtrics link for online version) → Receive and Code Responses → Survey statistical analysis

↓

Analysis and Key Findings

Results

1. Familiarity with TWDB's water supply strategies
2. **Frequency in Communication with TWDB**
3. Scale of agency
4. Type of agency



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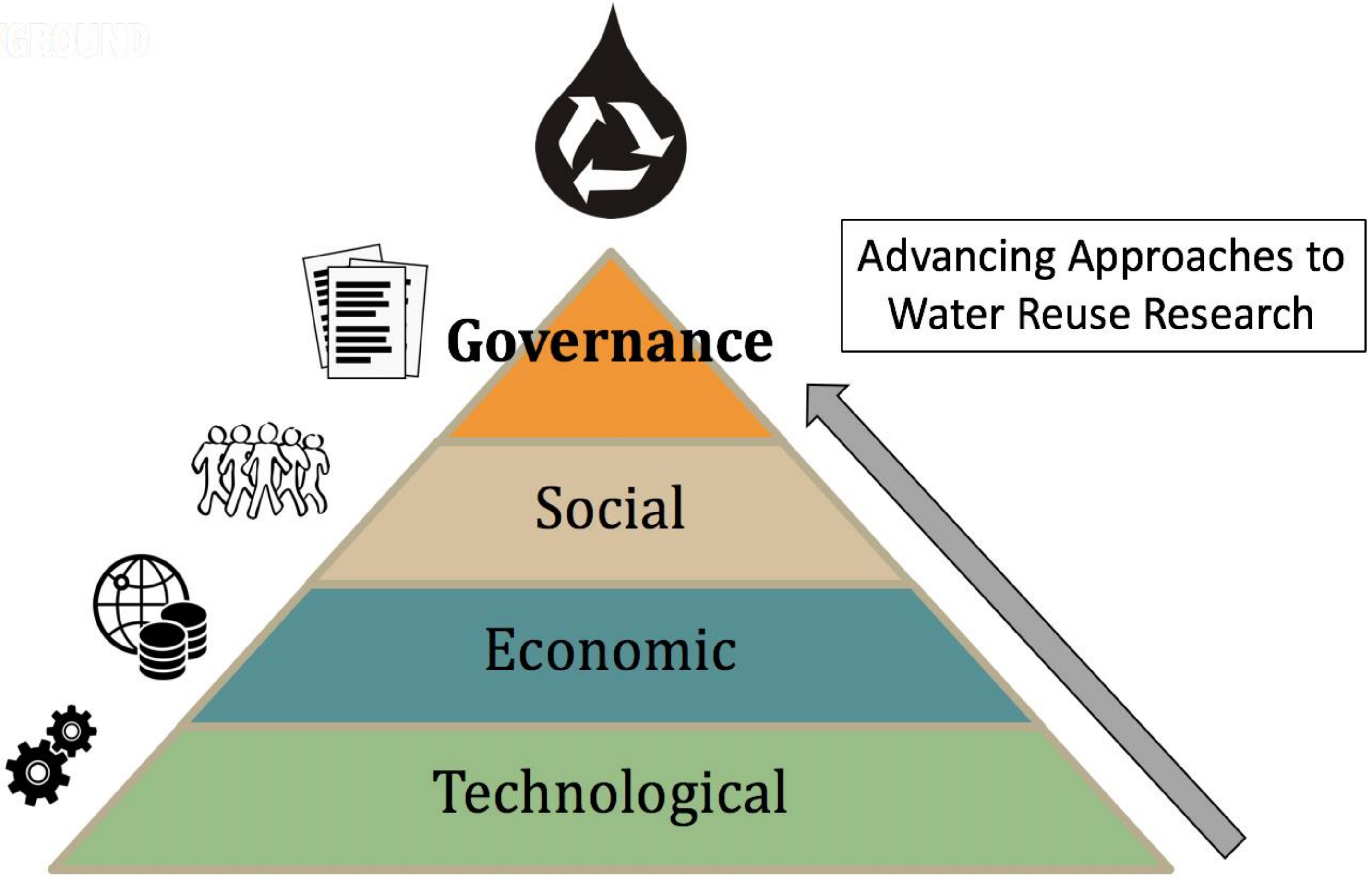
Key Messages

- 58% of agencies do not communicate with the Texas Water Development Board.
- Increased communication is needed.
- Improved water governance



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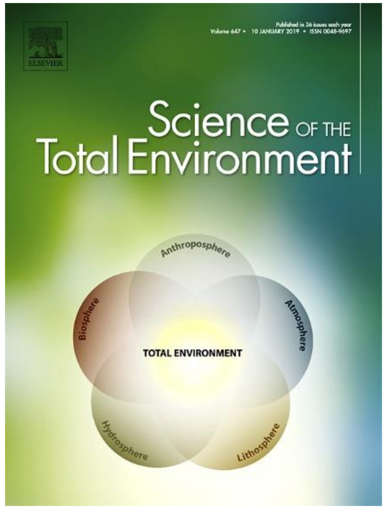

Toward creating an environment of cooperation between water, energy, and food stakeholders in San Antonio

Bassel ***Daher***, *Bryce* ***Hannibal***, *Kent E.* ***Portney***, *Rabi H.* ***Mohtar***

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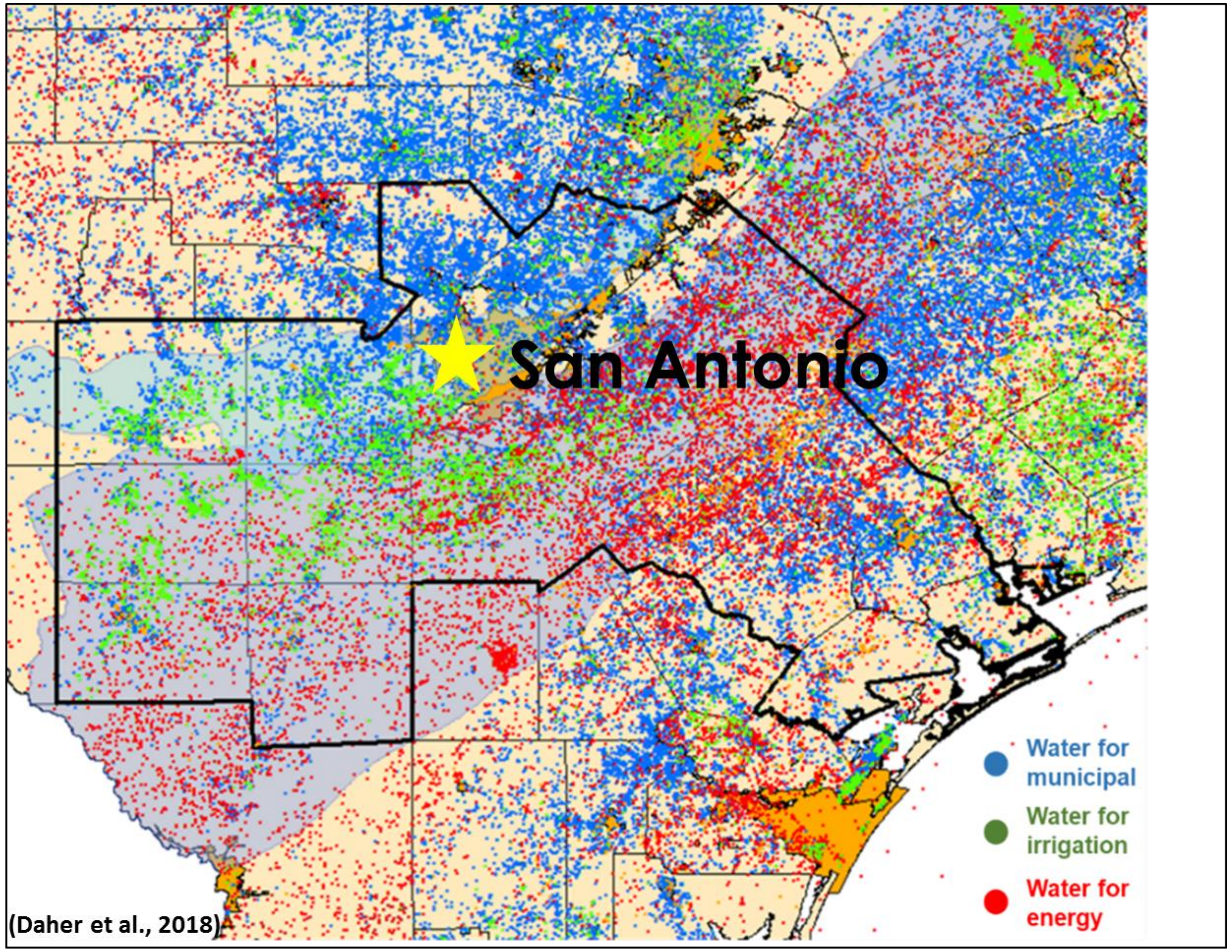
Background and Study Objectives



OBJECTIVES

1) **Quantify** current **levels of communication** between decision makers within water, energy, and food sectors.

2) **Evaluate** the relation between water officials' ***perception* of future water challenges** and ***levels of* communication.**

3) **Evaluate** the relation between **participation in resource planning stakeholder forums** and **levels of communication.**

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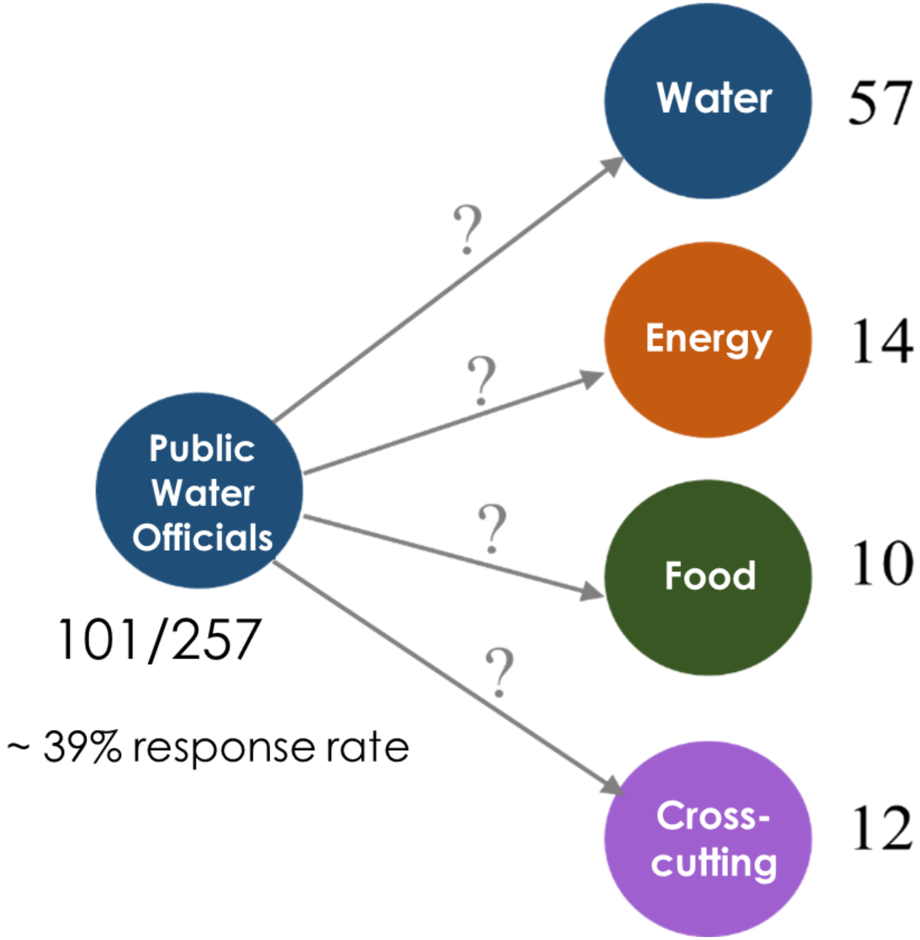
Methods

Survey with Water Officials in San Antonio



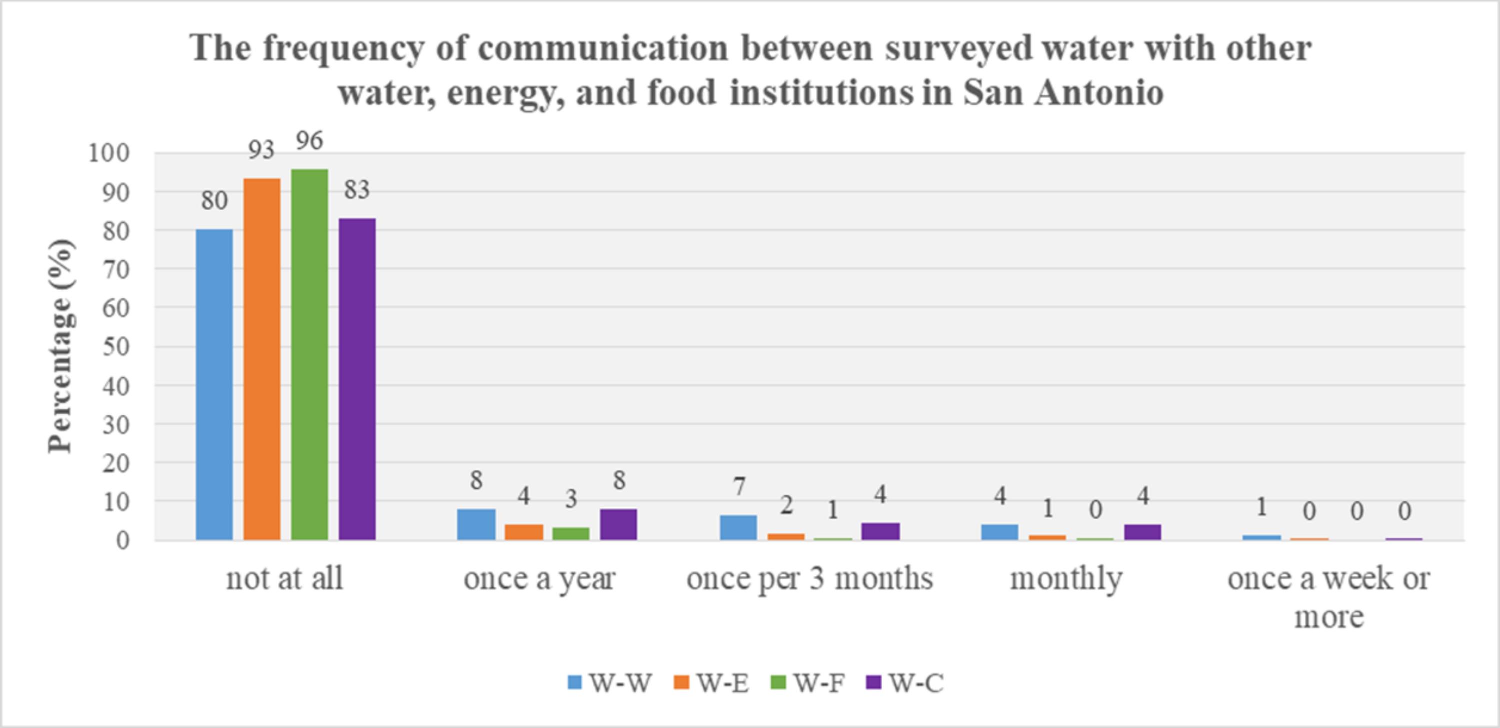
Methods for Stakeholder Identification and classification

- Scoping/literature web search
- Self-identification

Methods for Stakeholder Relations

- Social Network Analysis

Results



- Low overall level of communication
- Communication between WW > WE (statistically sig.)
- WW~WF~WC

Table 3: P-value results for t-test for WW vs WF, WW vs WE, WW vs WC averages

Comparisons	*Hypothesis*	*P-value (t-test)*	*Decision*
WW vs WF	H1: μ (ww) > μ (wf)	$p<0.967$	No Support for H1
WW vs WE	H1: μ (ww) > μ (we)	$p<0.001$	Support for H1
WW vs WC	H1: μ (ww) > μ (wc)	$p<0.998$	No support for H1

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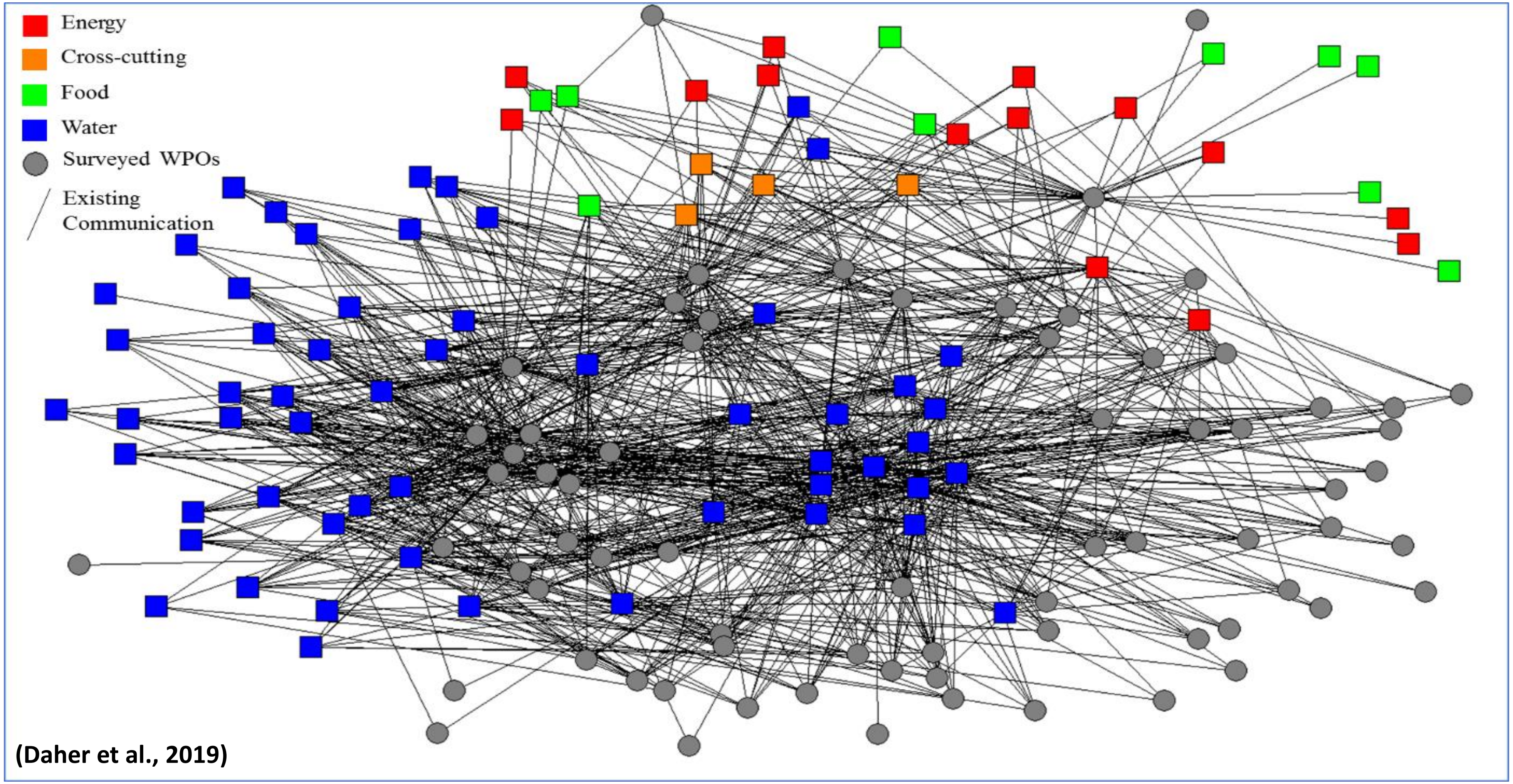
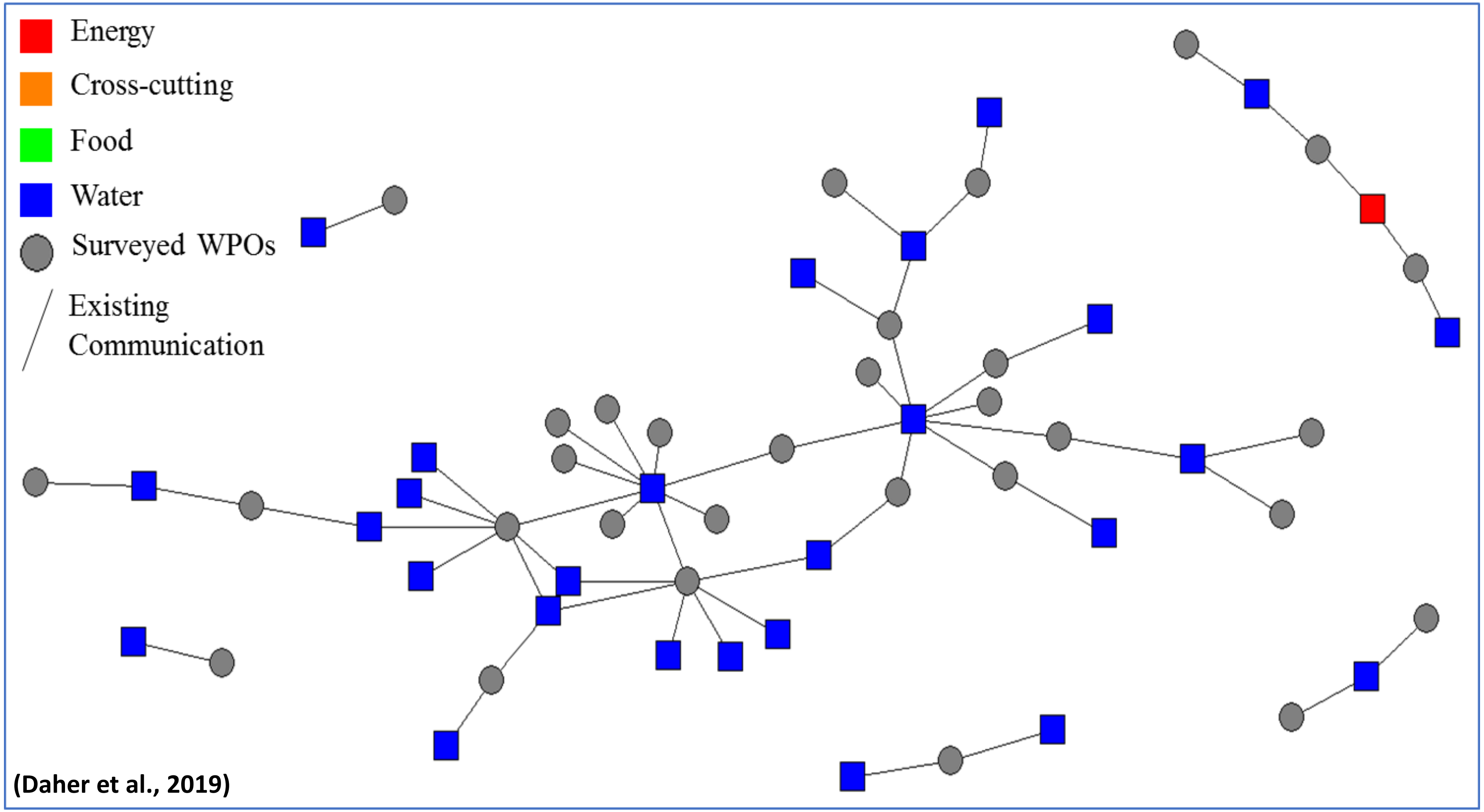
Network Map – **any level** of communication



(Daher et al., 2019)

Network map for **weekly** communication



Key Messages

1. Importance of combining **bio-physical** and **social** data and analysis.
2. **Interconnected resource challenges**, yet **low levels of communication** across sectors.
3. Higher levels of communication **among water officials**, compared to **water with energy.**
4. **Positive correlation**: attending **stakeholder integrative planning forums** and higher communication **among water officials only.**
5. **Insufficient evidence**: relation between **level of communication** & **concern about water availability.**
6. Need to invest in development of **cross-institutional mechanisms** that promote higher levels of communication, with sufficient allocation of funds and time.
7. **Integrative planning workshops: more inclusive.** particularly of members from **energy sector.**

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Q&A 5

Governance (15 min)

CST: 9:42 am | Beirut: 5:42 pm

Aldaco-Manner, L., Mohtar, R., & Portney, K. (2019). Analysis of four governance factors on efforts of water governing agencies to increase water reuse in the San Antonio Region. Science of the Total Environment, 647, 1498-1507. doi:10.1016/j.scitotenv.2018.07.366

Daher, B., Hannibal, B., Portney, K. E., & Mohtar, R. H. (2019). Toward creating an environment of cooperation between water, energy, and food stakeholders in San Antonio. Science of the Total Environment, 651, 2913-2926. doi:10.1016/j.scitotenv.2018.09.395

Q/A

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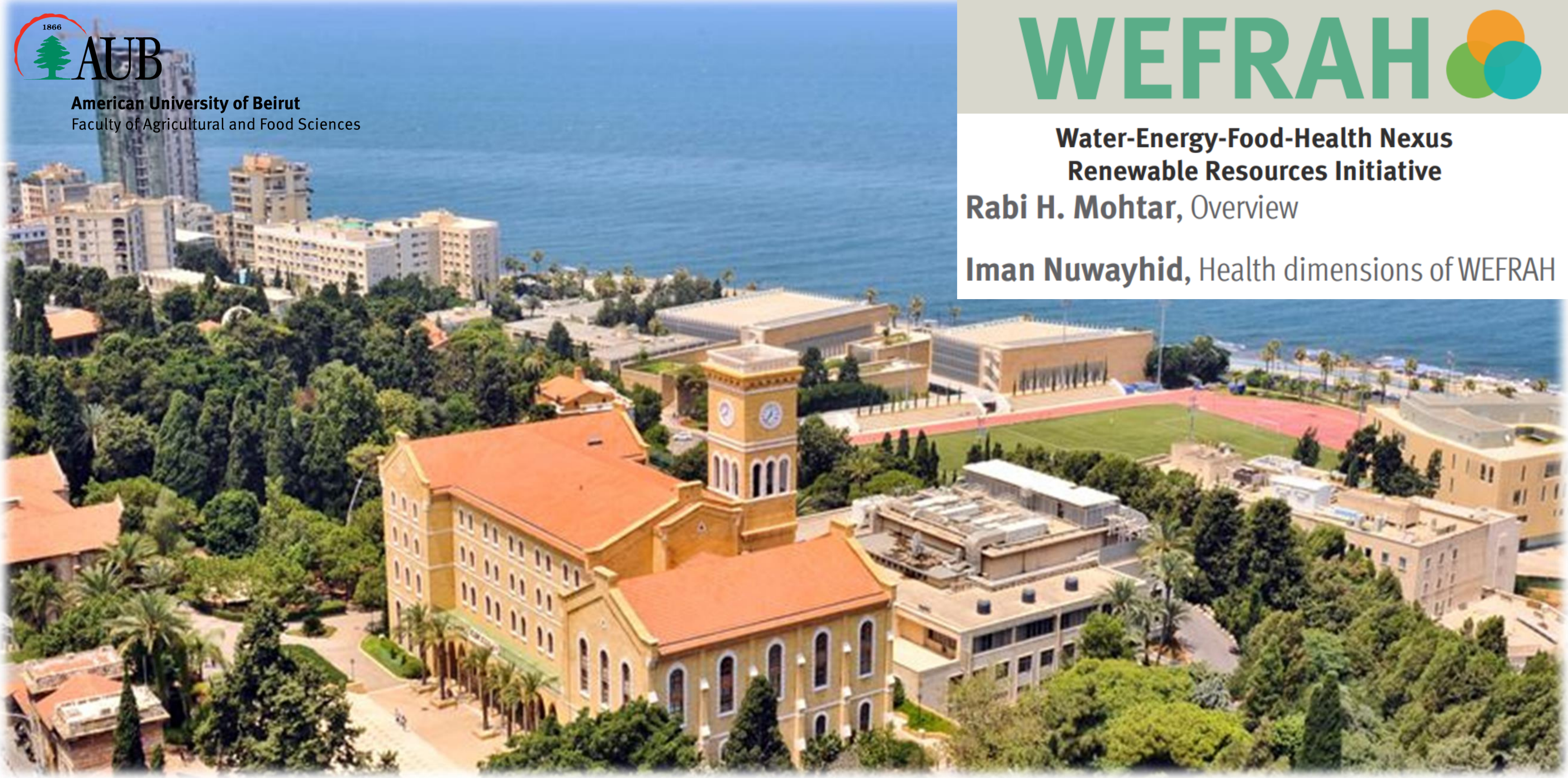

WEFRAH

Water-Energy-Food-Health Nexus
Renewable Resources Initiative

Rabi H. Mohtar, Overview

Iman Nuwayhid, Health dimensions of WEFRAH

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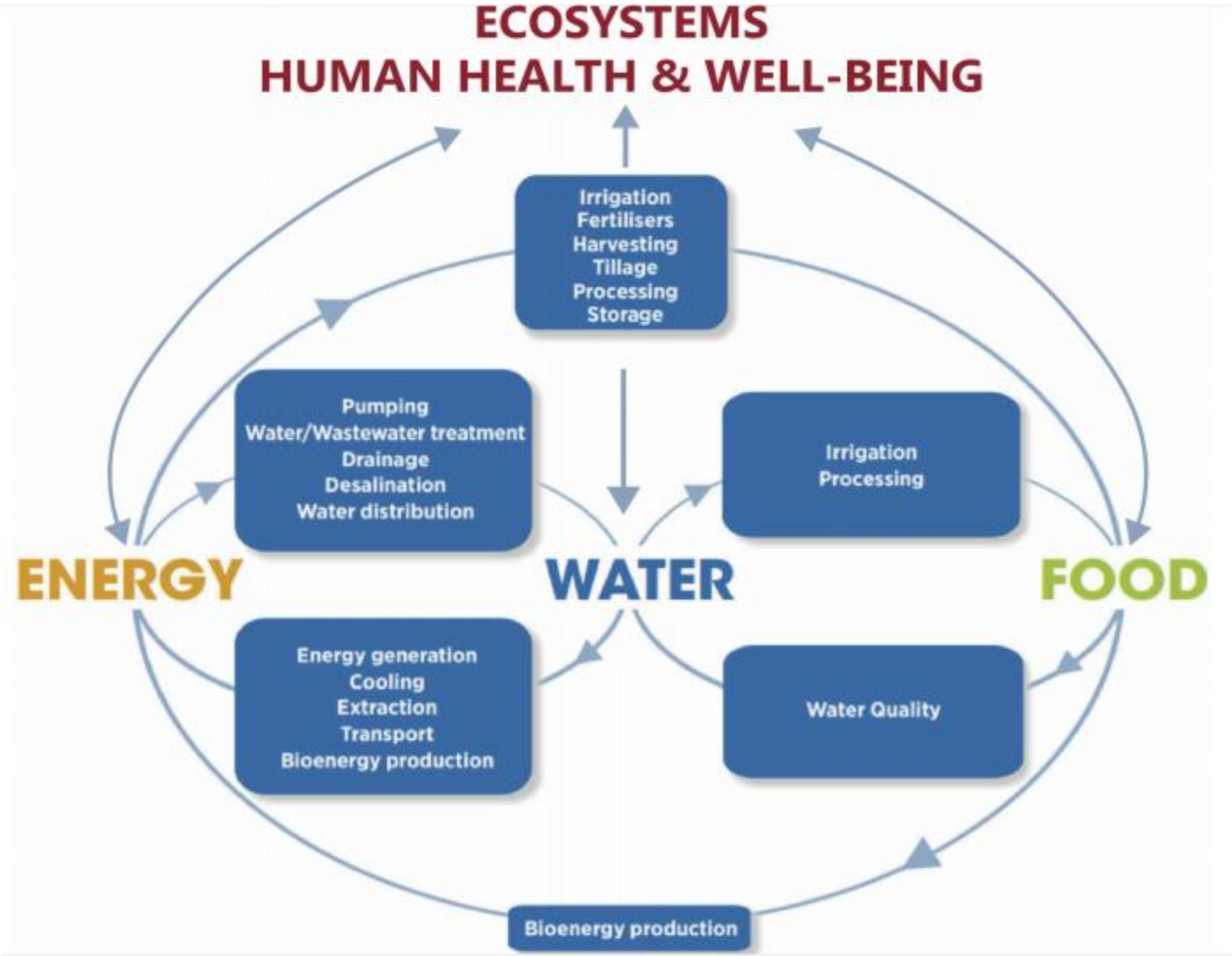
Water – Energy – Food – Health Nexus: Renewable Resources Initiative (WEFRAH)

WEFRAH

Goals

1. Understand complexities;
2. Reduce interdependencies;
3. Increase resilience;
4. Promote ecosystems and human health & well-being.



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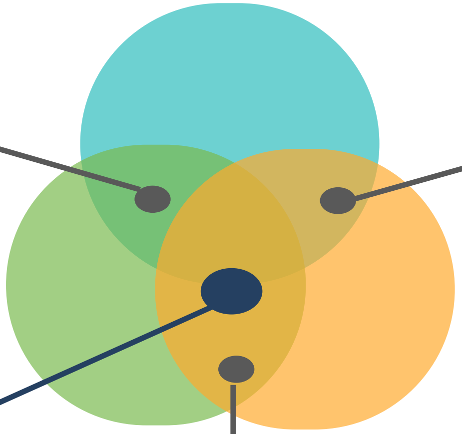
Create Synergies – Reduce Dependencies: Selected Examples

Water-Food

- From water **efficiency** to water **productivity**
- Breeding and **genetic** modification
- **Dryland** agriculture
- Urban farming



Water-Energy

- Less **water for energy** production (air cooling, non-hydraulic shale production)
- Full **recovery/reuse** of industrial & produced water
- Less **energy for water** production and transport

Cross Cutting

- WEFH Systems learning and capacity building
- Impact on human and natural system
- Governance and policy coherence
- Modeling the complex system of the water-energy-food-health nexus
- Impact of localized holistic solutions on national sustainable development goals (SDGs) plans.

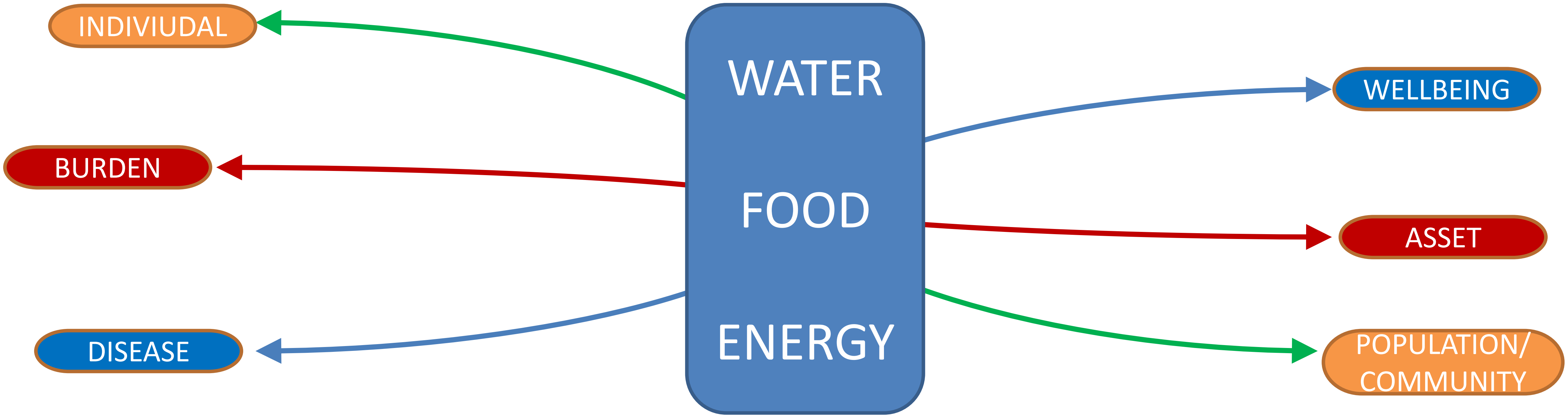
Energy-Food

- Next generation **biofuel**
- Less **energy for food** production, processing & transport
- **Biomass** full energy recovery
- Reduction of Food waste

Health - WEF

- Reconstituted water (**Desalination**) impact on human health
- Renewables, carbon emission (**air quality)** impact on human health
- Climate, **eco-zones**, land use changes and diseases
- Water, food, nutrition and **non-communicable diseases (NCDs)**

Health as a Renewable Resource Too



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Moving Forward

1. SDG case studies at different scales
2. Establish a WEF Nexus community of science & practice
3. Expand on system’s approach for understanding interconnected resource challenges
4. The genie is out!
5. Explore policy, technological, social interventions
6. Education and capacity building
7. Emphasize the role of health in WEF Nexus

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