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XIX WORLD WATER CONGRESS
International Water Resources Association (IWRA)
Marrakech, Morocco | 1-5 December 2025

Kingdom of Morocco
Ministry of Equipment and Water

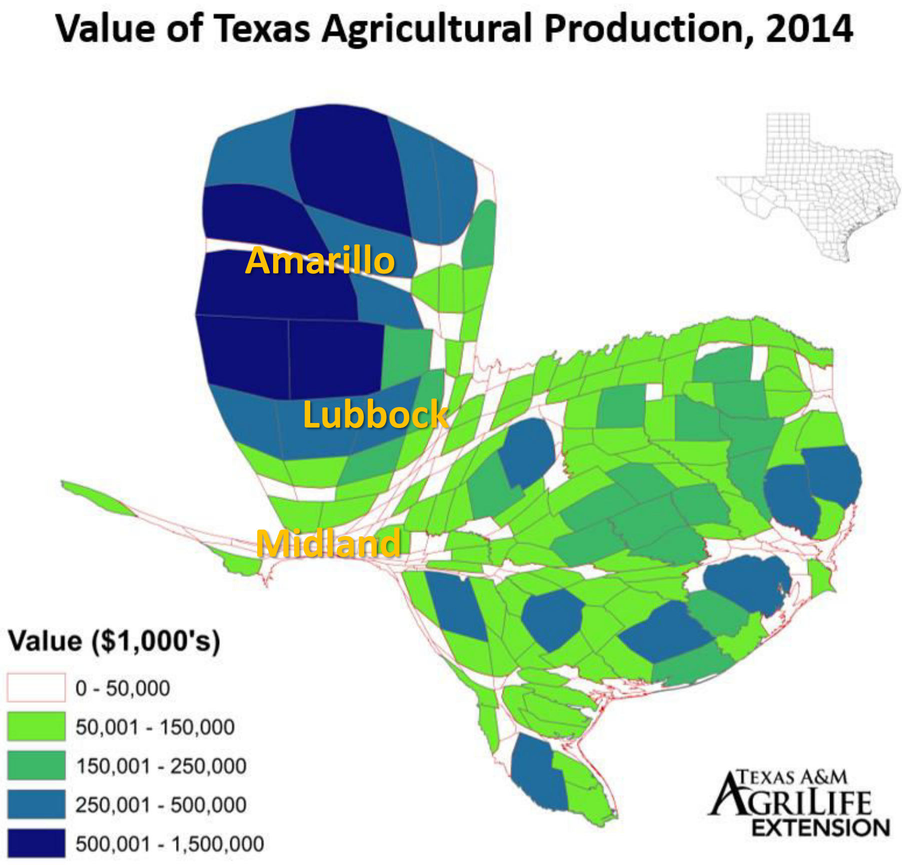
Application of treated produced water influence chemical and biological properties of two semi-arid soils

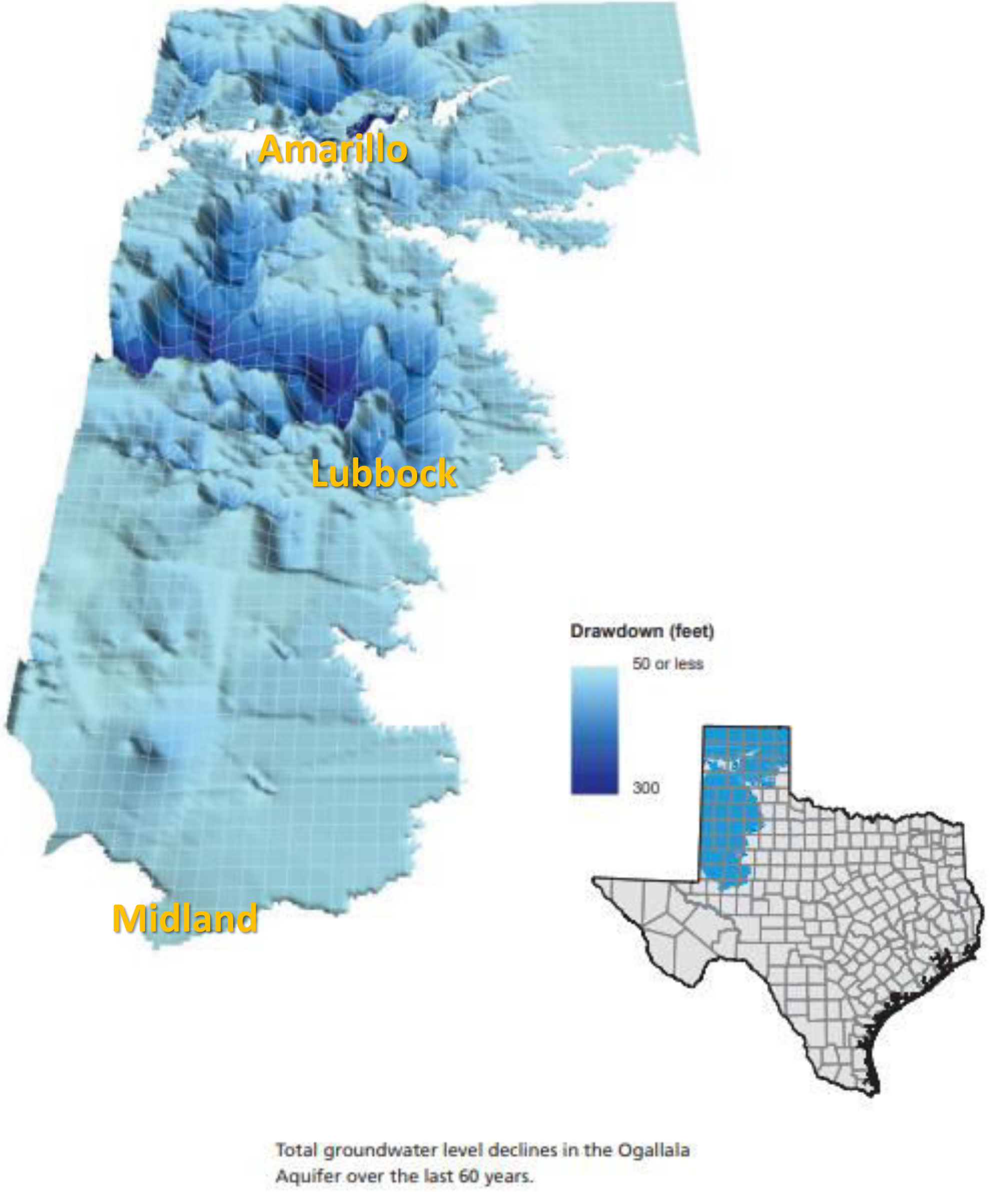
Joseph A. Burke[1], Katie L. Lewis[1], Shankar Chellam[2], Hensley Repak[1,3] Noel Beltran[1,4], and Hector Valencia[1]

[1]Texas A&M AgriLife, Lubbock, TX, USA, [2]Texas A&M University, College Station, TX, USA, [3]Texas Tech University, Lubbock, TX, USA, [4]University of Puerto Rico-Mayaguez, Mayaguez, Puerto Rico, USA

4 December 2025

Texas agriculture





Texas Water Development Board Report 380

Everything is bigger in Texas

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2.04 B

barrels of oil in 2024

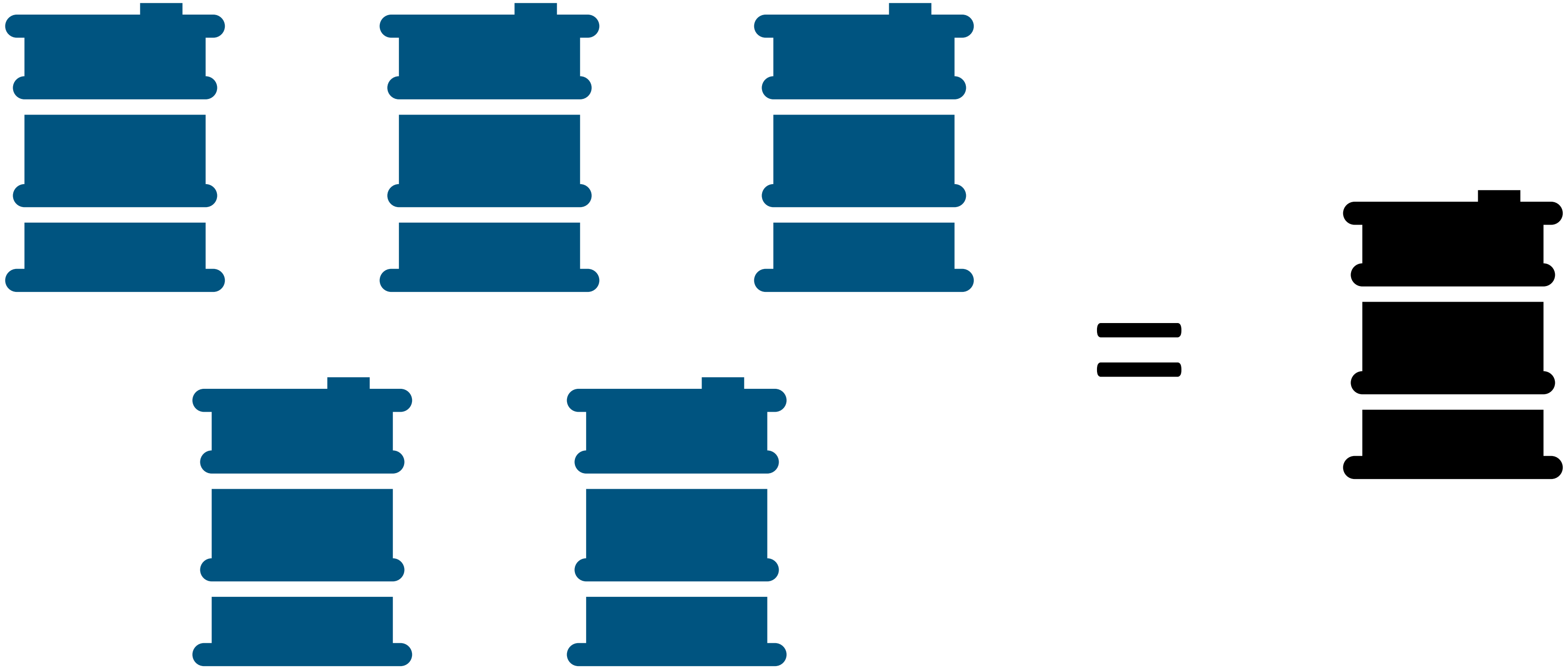
12.8 Tcf

of natural gas in 2024

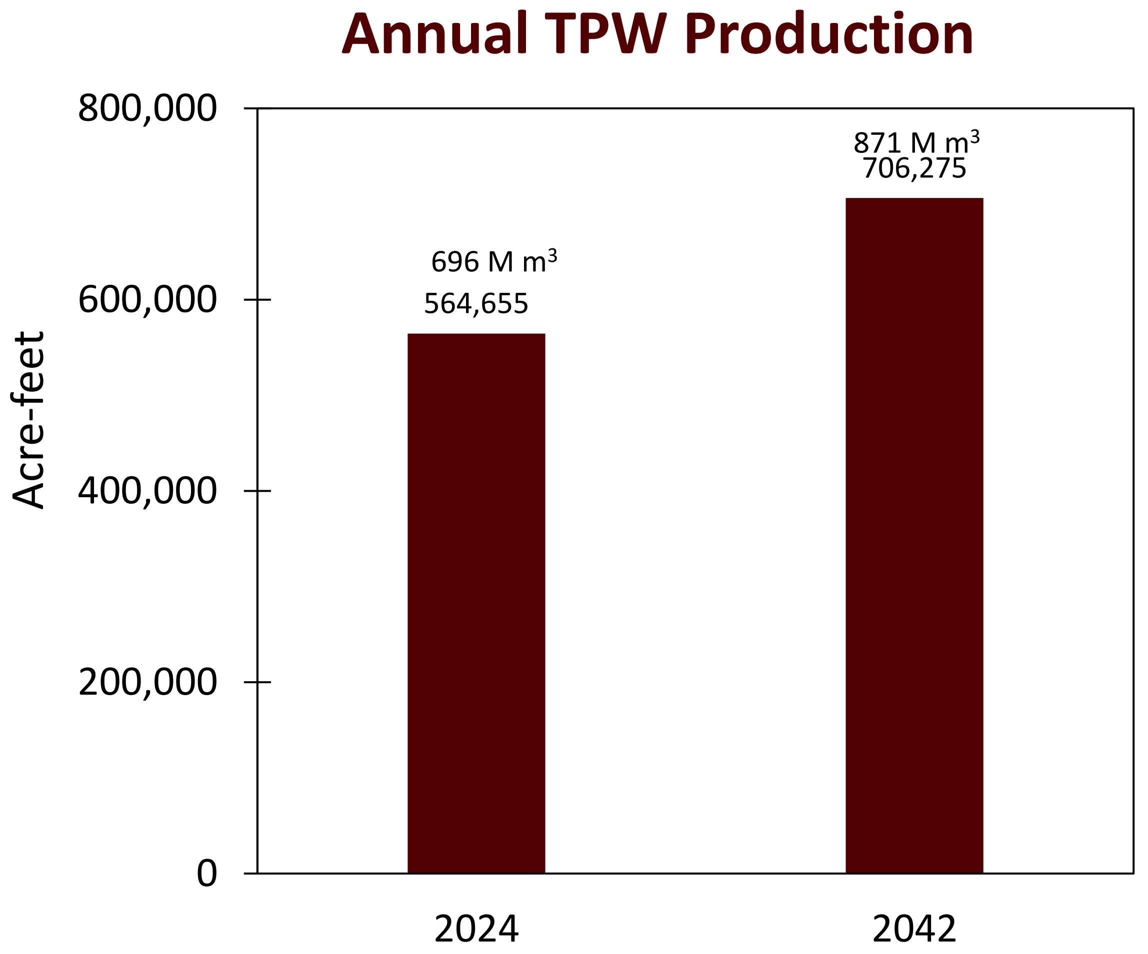
$23.7 B

paid in local & state taxes and royalties

Everything is bigger in Texas



Everything is bigger in Texas



Opportunities for Agriculture

- Resource recovery hovers around 50%
  - 2024 – 280,000 acre-feet or 345 M m^3
  - 2042 – 350,000 acre-feet or 432 M m^3
- Expected increase in resource recovery
  - High-value minerals in produced water
  - State initiatives in desalination – SB7 invests $1B annually in water projects for 20 yr

So why aren't we already using treated produced water for agriculture?

“Treated” water

Parameter	Unit	Value
pH	----	6.5
SAR	----	141
TDS	ppm	62,720
EC	mmho/cm	105
Total hardness	ppm	19,320
Total organic C	ppm	1,705

Parameter	Unit	Value
Sodium	ppm	45,087
Calcium	ppm	6,117
Magnesium	ppm	967
Potassium	ppm	1,424
Sulfur	ppm	192
Chloride	ppm	99,077
Boron	ppm	18
Silica	ppm	14
Ammonium	ppm	1,117
HCO_3	ppm	208
Phosphorus Zinc Iron Manganese Nickel Arsenic Lead	Copper Molybdenum Chromium Cobalt Selenium Cadmium	< 1 ppm

Produced water management

Water dilution evaluation

PW:TW	pH	EC	Cl	K	Ca
	----	*mS cm^{-1}*	*Ppm*		
0:1	8.5	6.3	2,200	23	54
1:0	7.1	186.3	> 33,000	2,900	>10,000
1:1	7.7	56.4	> 33,000	1,275	5,000
1:2	7.7	54.2	> 33,000	718	2,625
1:5	7.8	45.4	> 33,000	158	708
1:10	7.9	23.7	17,667	38	185
1:25	8.0	13.1	8,900	18	54
1:50	8.0	8.7	4,550	2	35
1:100	8.1	5.8	2,425	0.9	38

TW, Lubbock tap water

Brine-Aid rate evaluation

BA:PW	pH	EC	Cl	K	Ca
	----	*mS cm^{-1}*	*ppm*		
1:1	5.9	126.2	> 33,000	748	4.0
2:1	6.2	170.1	> 33,000	1,375	10.0
5:1	6.4	190.2	> 33,000	2,000	57.0
20:1	6.9	196.9	> 33,000	2,675	1,193.0
40:1	6.7	190.5	> 33,000	2,850	4,300.0
1:2	5.5	120.6	> 33,000	283	1.3
1:5	5.3	91.5	> 33,000	51	0.6
1:20	5.1	81.8	7,833	8	0.4
1:40	5.0	79.0	3,175	3	0.3

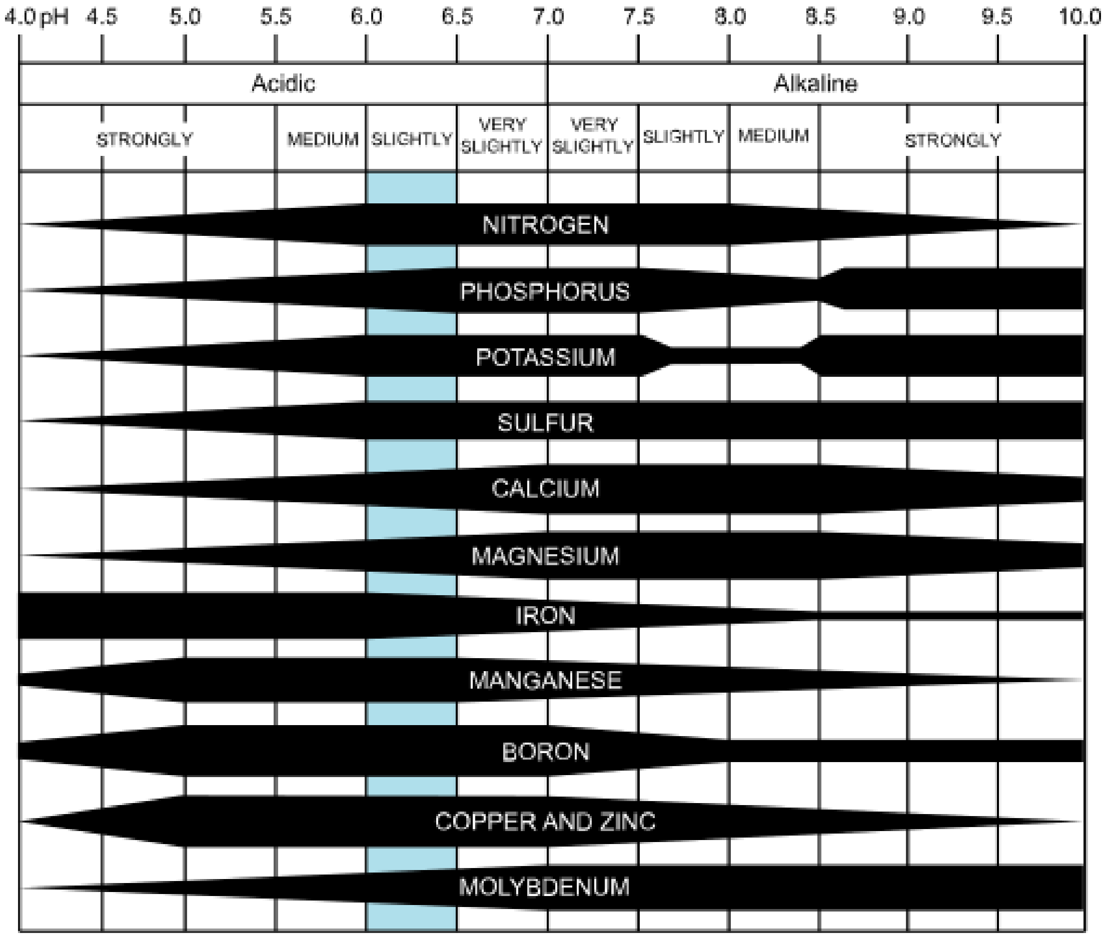
Experimental design

Project Goal – Evaluate two treatment options to purify produced water from unconventional oil and gas operations so that it can be reused to irrigate non-consumptive agricultural crops.

Engineering –
- Bench-scale experiment
- Water treatments:
  - Year 1 – coagulation-flocculation-clarification to generate a clear brine with > 90% turbidity removal
  - Year 2 – desalination by humidification-dehumidification and osmotically-assisted reverse osmosis to generate a brine with > 50% total dissolved solid removal

Soil science –
- Microcosm experiment
- Soil types –
  - Fine sandy loam (Aridic Paleustalfs)
  - Loam (Aridic Paleustolls)
- Incubation –
  - 60% water-filled pore space
  - Duration – 56 days (7, 14, 28 and 56 d)
  - Temperature – 28°C
  - Measurables – pH, electrical conductivity, carbon mineralization, enzyme activities

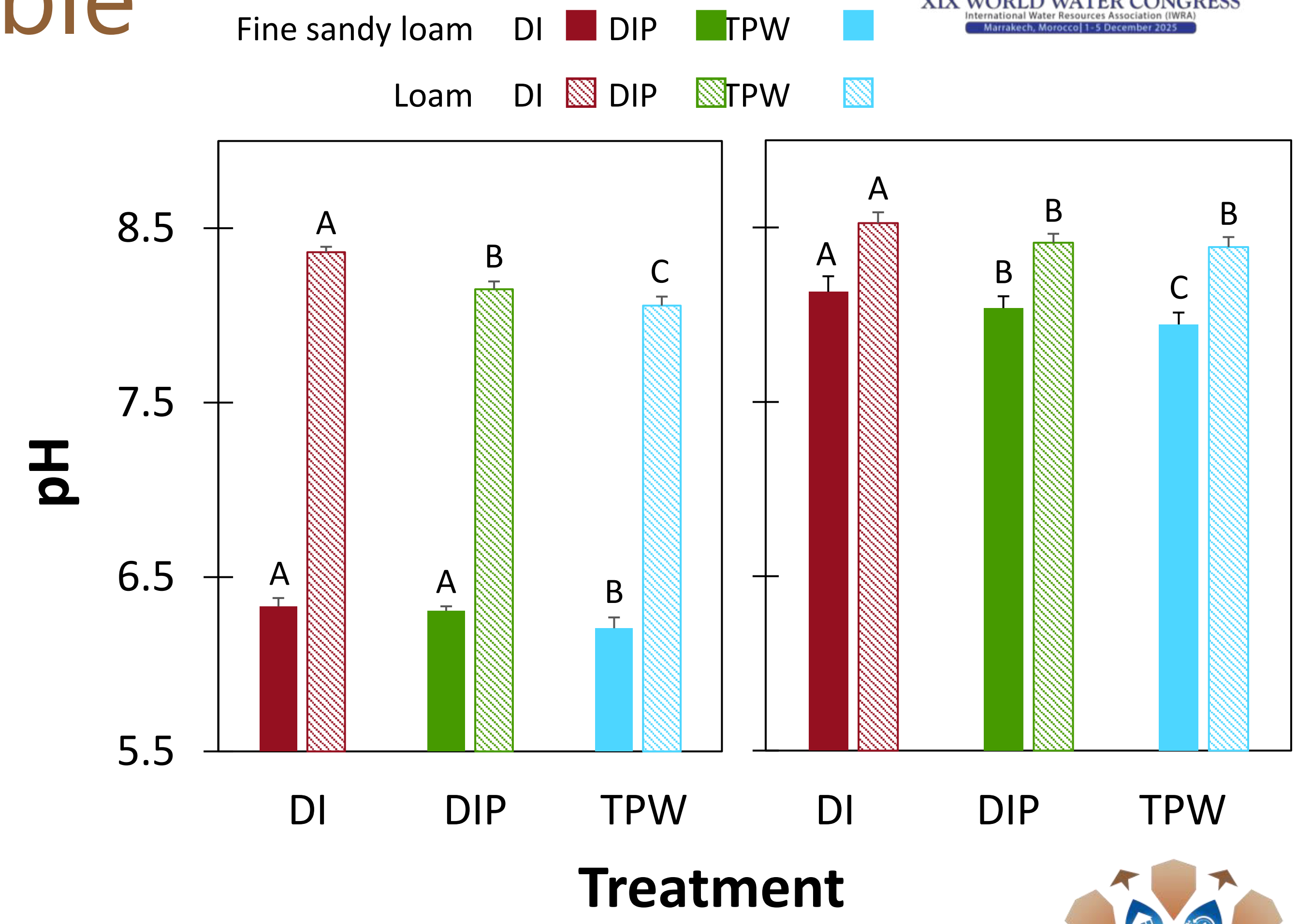
pH – The master variable



- pH is a key indicator of soil function. It is responsible for most physical, chemical, and biological activities in soil, especially nutrient availability.
- Plant-essential nutrients are most readily available in near-neutral soils. However, few soils are naturally neutral, limiting nutrient availability.
- How will treated produced water applications influence pH, and subsequently, nutrient availability?

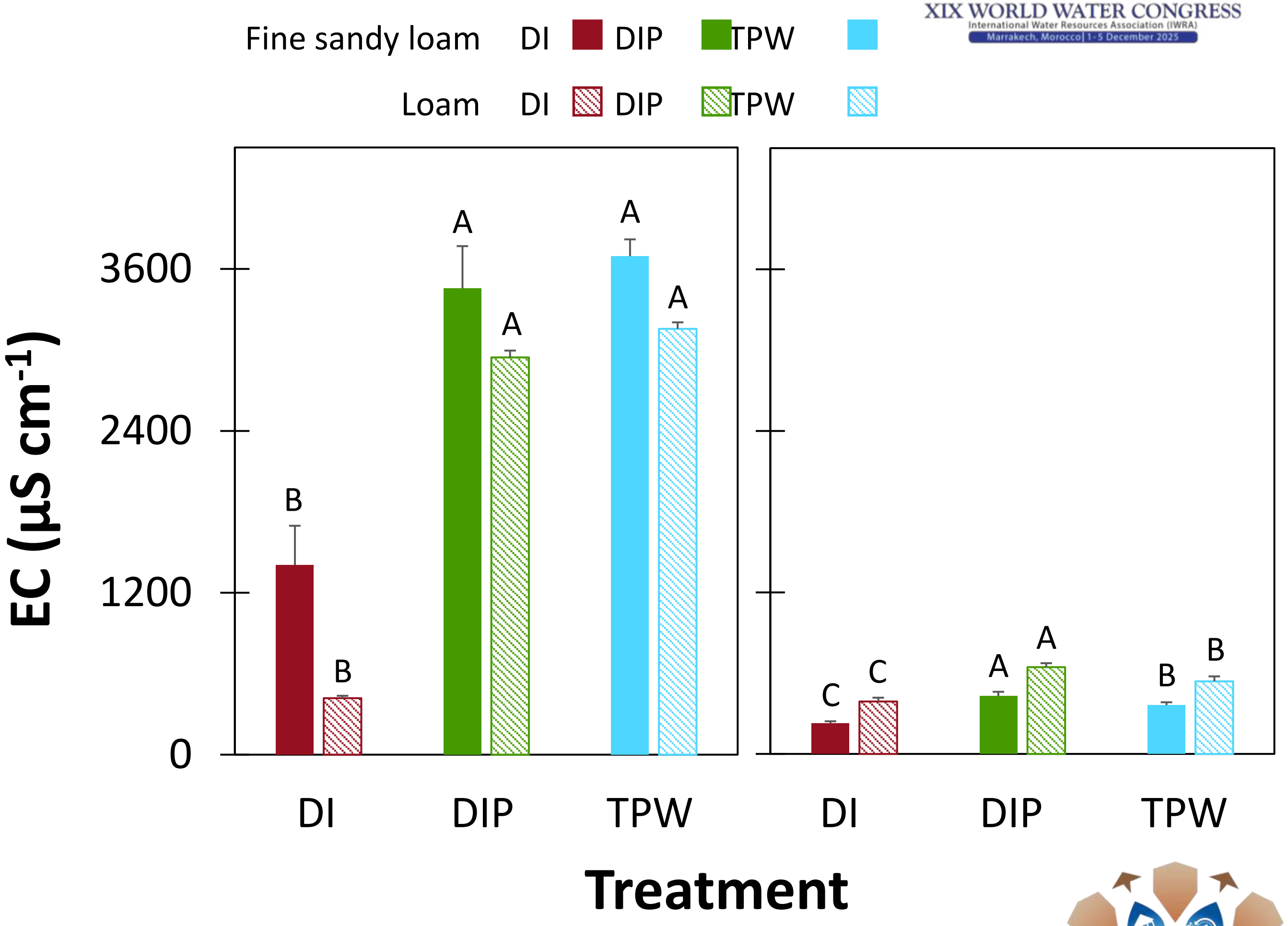
pH – The master variable

- In 2024 (left)
  - Fine sandy loam:
    - Soil pH was inherently reduced compared to the loam.
    - TPW reduced pH compared to DI & DIP.
  - Loam
    - The addition of DIP and TPW reduced pH compared to DI.
- In 2025 (right)
  - Fine sandy loam:
    - DIP and TPW reduced soil pH compared to DI, but the effect was greater with TPW.
  - Loam:
    - DIP and TPW reduced soil pH similarly compared to DI.
- Further research is needed to better understand which component of TPW is impacting pH.



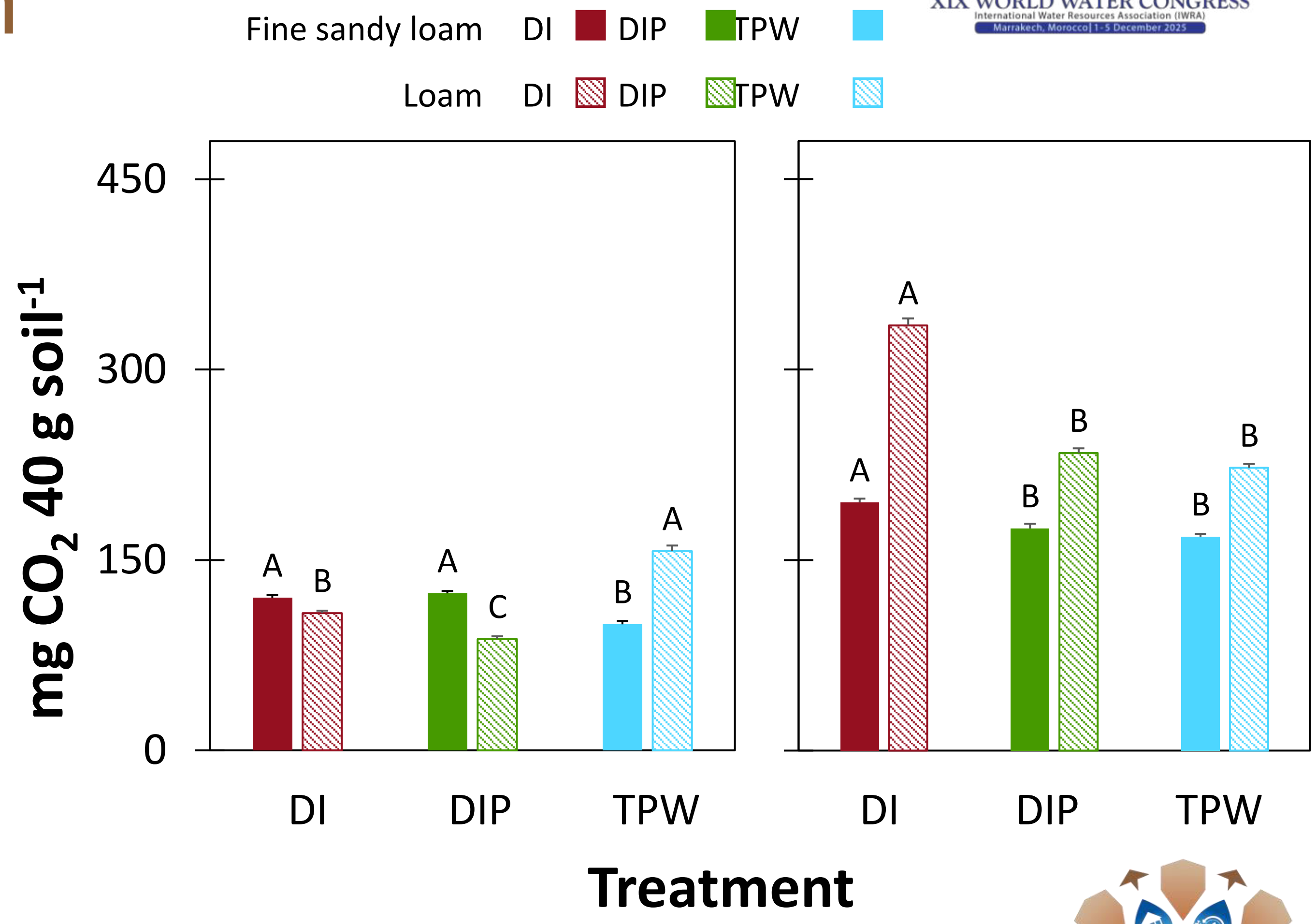
Electrical conductivity

- In 2024 (left)
  - Fine sandy loam:
    - Inherent EC was greater in the fine sandy loam compared to the loam soil.
    - The addition of PW increased EC compared to DI.
  - Loam
    - The addition of DIP and TPW increased EC compared to DI.
- In 2025 (right)
  - Fine sandy loam and Loam:
    - DIP and TPW increased EC compared to DI, but the effect was greater with DIP.
- Desalination significantly reduced salinity impacts on the soil compared to the coagulation-flocculation-clarification treatment.



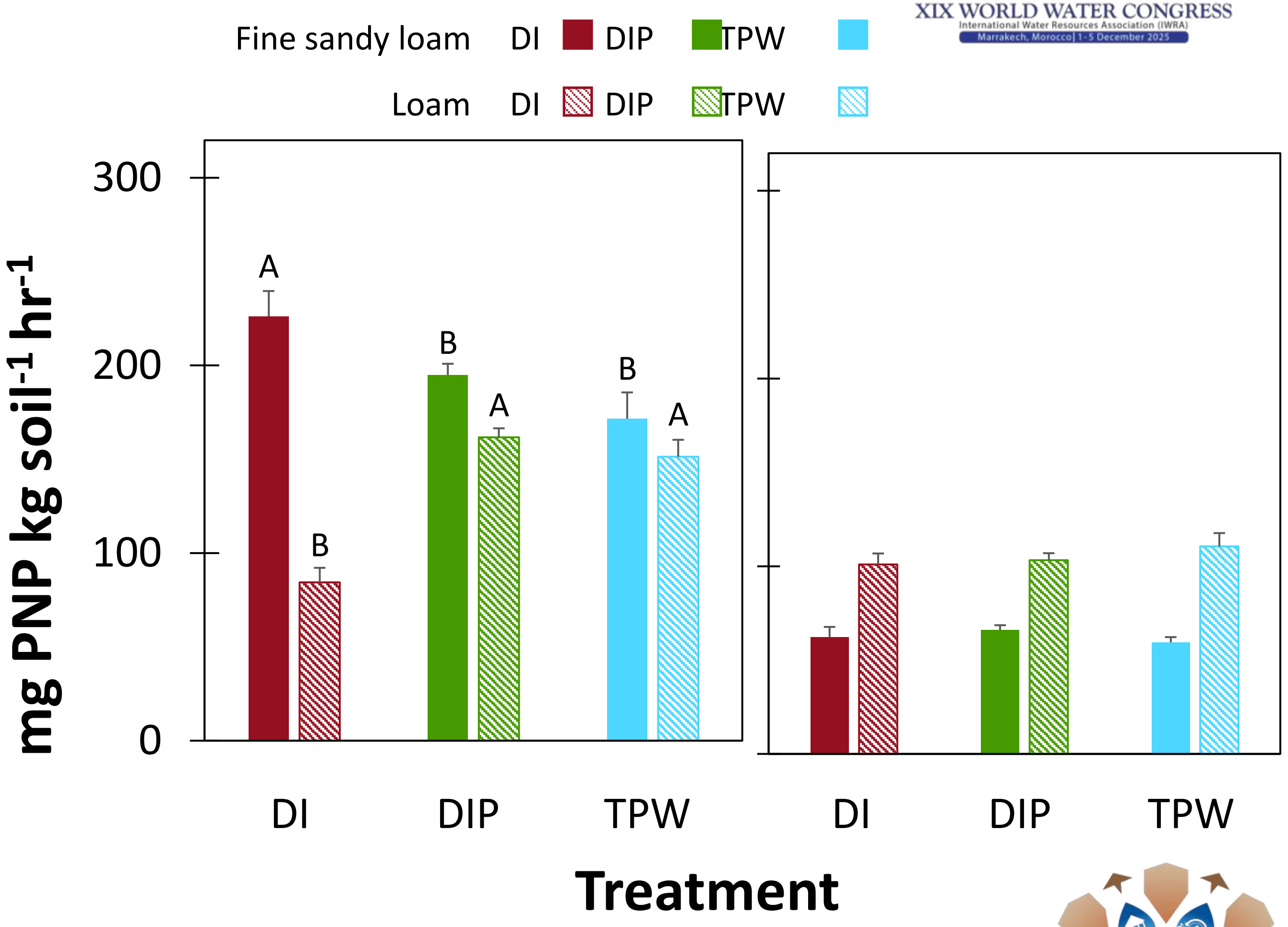
Carbon mineralization

- In 2024 (left)
  - Fine sandy loam:
    - TPW reduced MIN_C compared to DI & DIP.
  - Loam
    - TPW increased MIN_C compared to DI & DIP.
- In 2025 (right)
  - Fine sandy loam: and loam:
    - DIP and TPW reduced MIN_C compared to DI.
- Further research is needed to better understand which component of TPW is impacting carbon mineralization.



Enzyme activity

- Combined enzyme assay (β-glucosidase, N-acetyl-β-D-glucosaminidase, Phosphatase, and Arylsulfatase, Acosta-Martinez et al., 2018). A measure of nutrient cycling potential.
- In 2024 (left)
  - Fine sandy loam:
    - TPW and DIP reduced EA.
  - Loam
    - TPW and DIP increased EA.
- In 2025 (right)
  - Fine sandy loam and loam:
    - No differences.
- Further research is needed to better understand which component of TPW is impacting enzyme activity..



Summary and future experiments

- The addition of treated produced water had variable impacts on soil:
  - pH – treated produced water decreased soil pH regardless of water treatment.
  - Electrical conductivity – treated produced water increased electrical conductivity, but to a lesser extent with desalination.
  - Carbon mineralization – treated produced water had variable impacts on carbon mineralization; however.
  - Extracellular enzyme activity – treated produced water had variable impacts on enzyme activity; however, the desalinated treated produced water did not have an impact.

- Future Experiments:
  - Evaluating the impact of microalgae applications in combination with treated produced water on soil properties
  - Greenhouse evaluation – determine the longer-term impacts of treated produced water applications on soil properties in a column experiment.

Acknowledgements

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make every drop count

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Thank you!

joseph.burke@ag.tamu.edu
txsoillab.com