

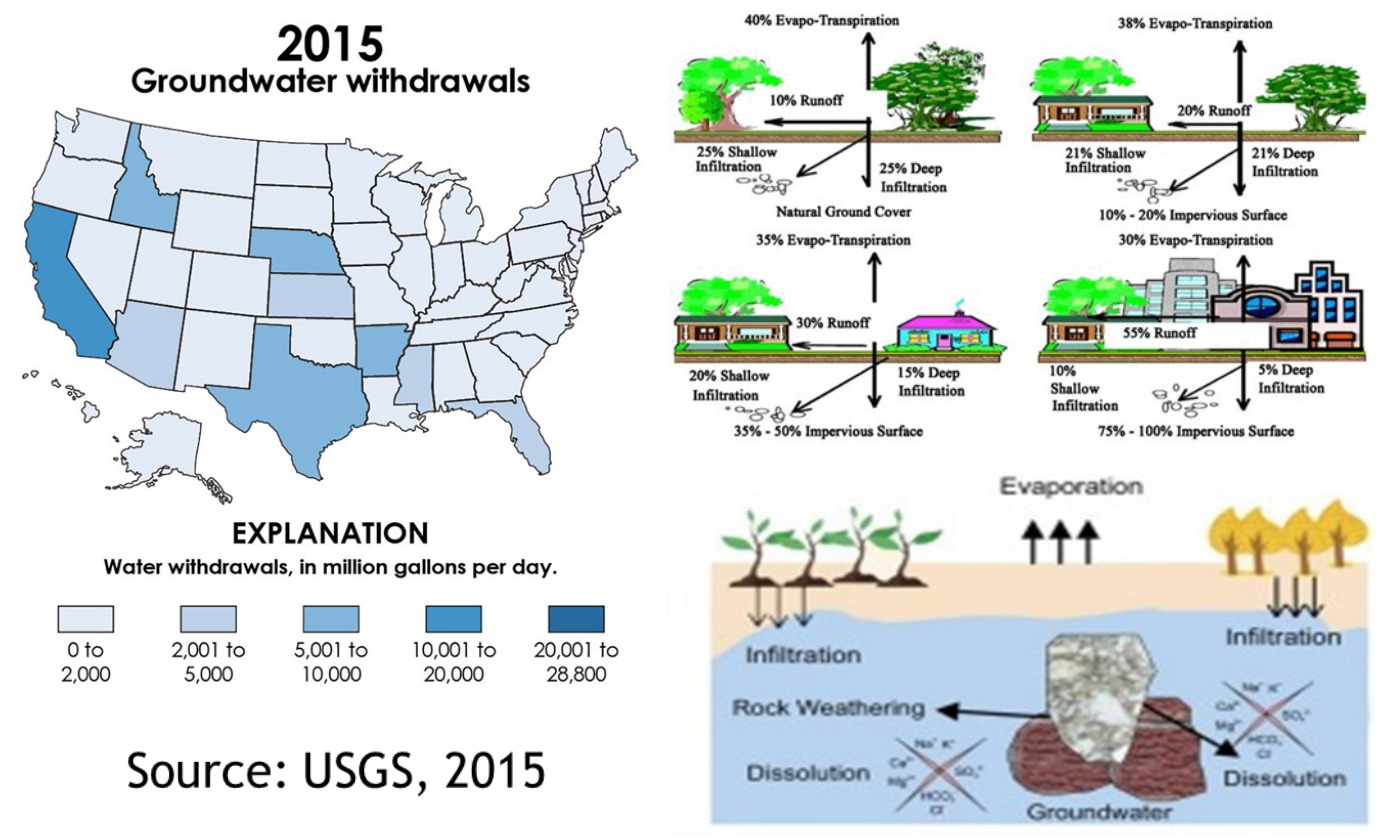
A Logistic Distribution-Based Assessment of the Spatiotemporal Evolution of Groundwater in Texas (1985-2024)

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INTRODUCTION

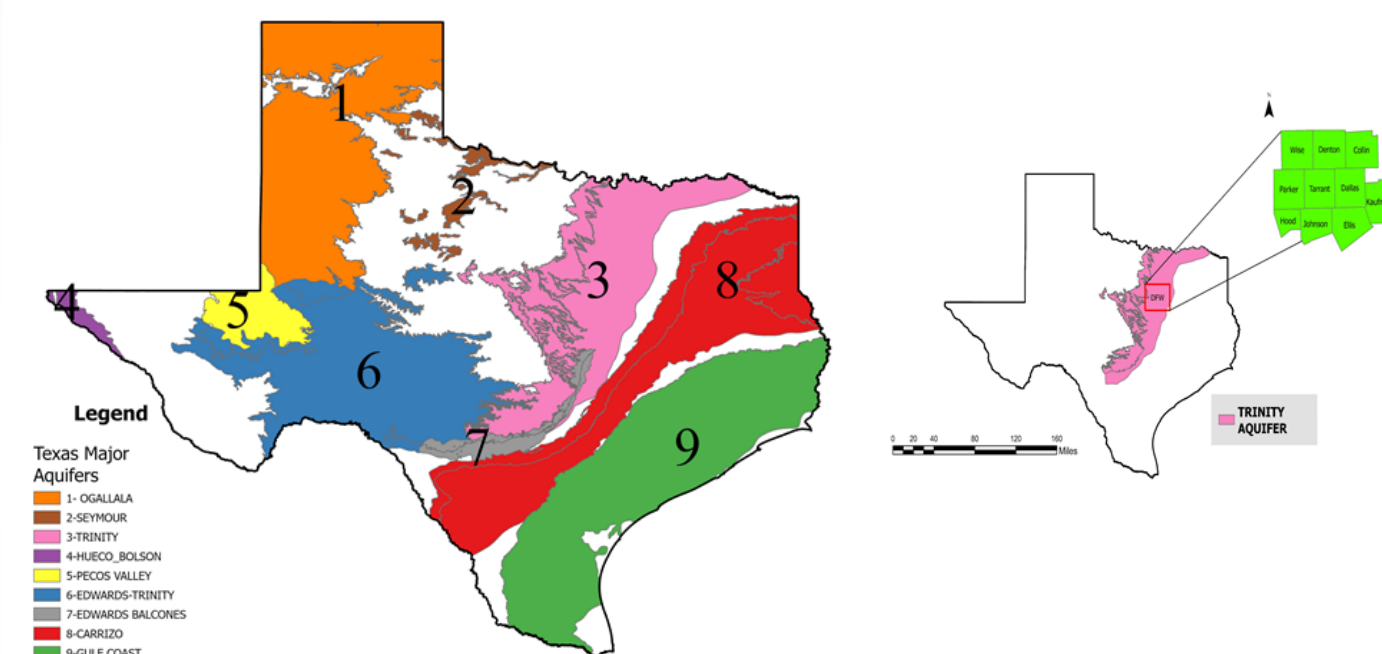


RESEARCH QUESTIONS

- How have land-use changes and population growth altered groundwater hydrogeochemistry across space (the nine major aquifers of Texas) and over time (1985–2014)?
- How has Population and Land use change over the last decade (2015-2024) influence groundwater chemistry in a 10 county region around DFW metropolplex?

STUDY AREA

Texas is underlain by nine major and twenty-two minor aquifers that collectively extend beneath approximately 79% of the State's land area and supply an estimated 60% of its total water use.



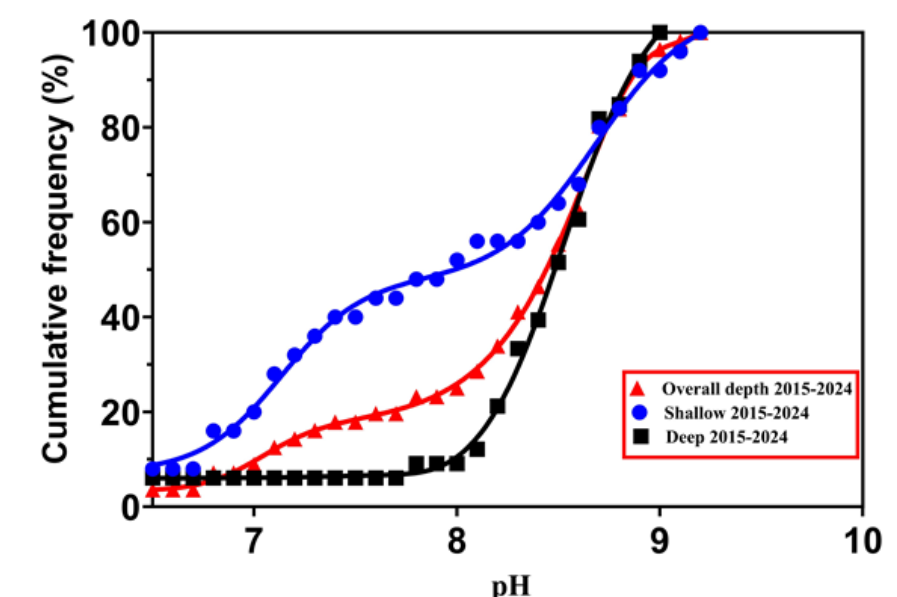
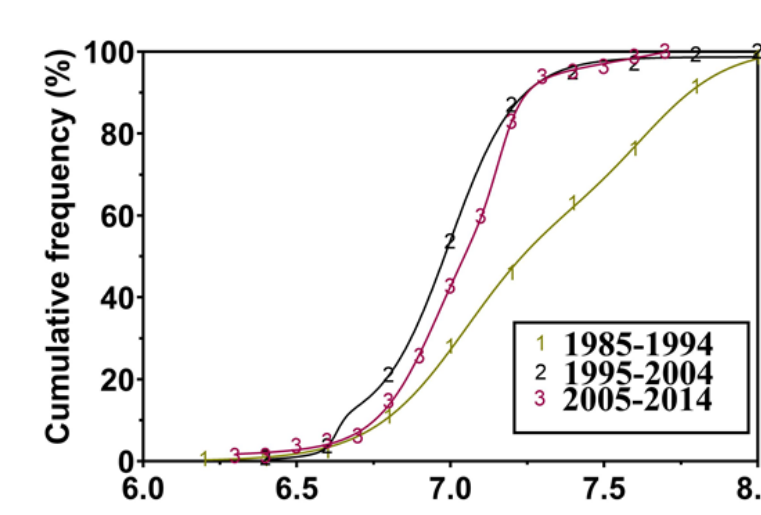
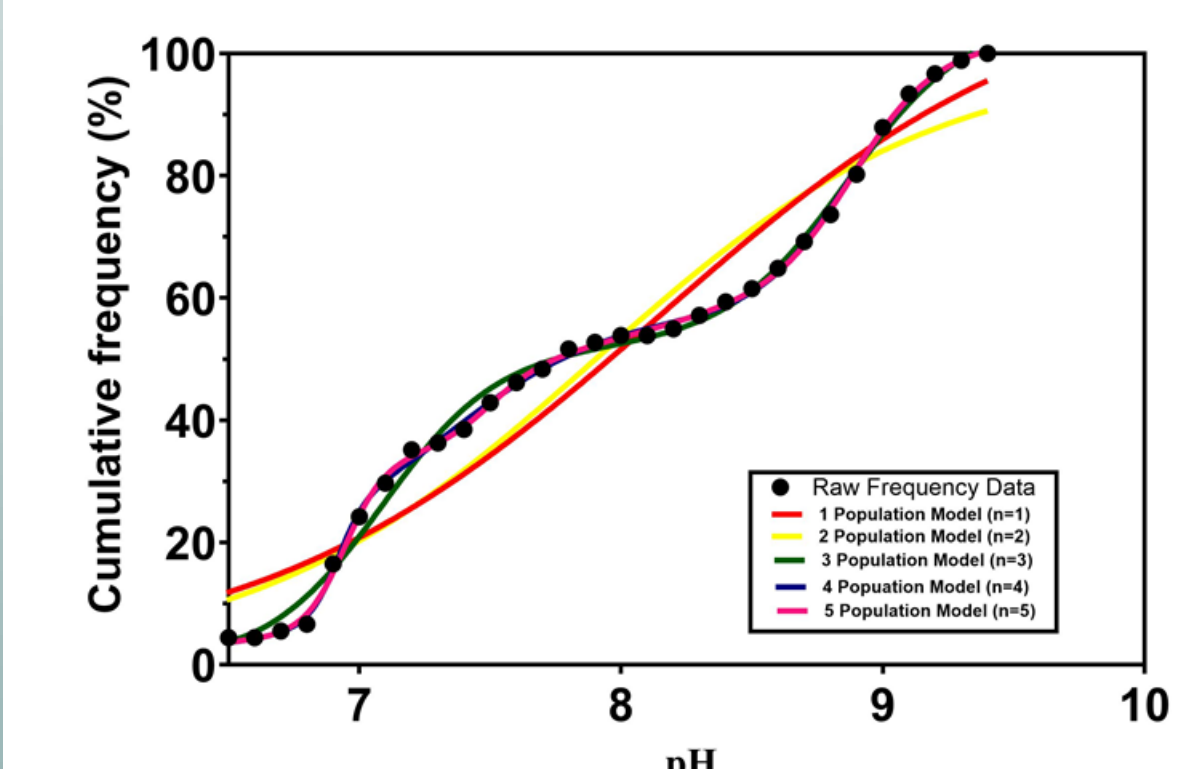
MATERIALS AND METHODS

- Data on groundwater wells for the nine major aquifers were acquired from the Texas Water Development Board and aggregated by decade: 1985-1994, 1995-2004, and 2005-2014.
- Data on groundwater wells for the 10 county region for the last decade 2015-2024.

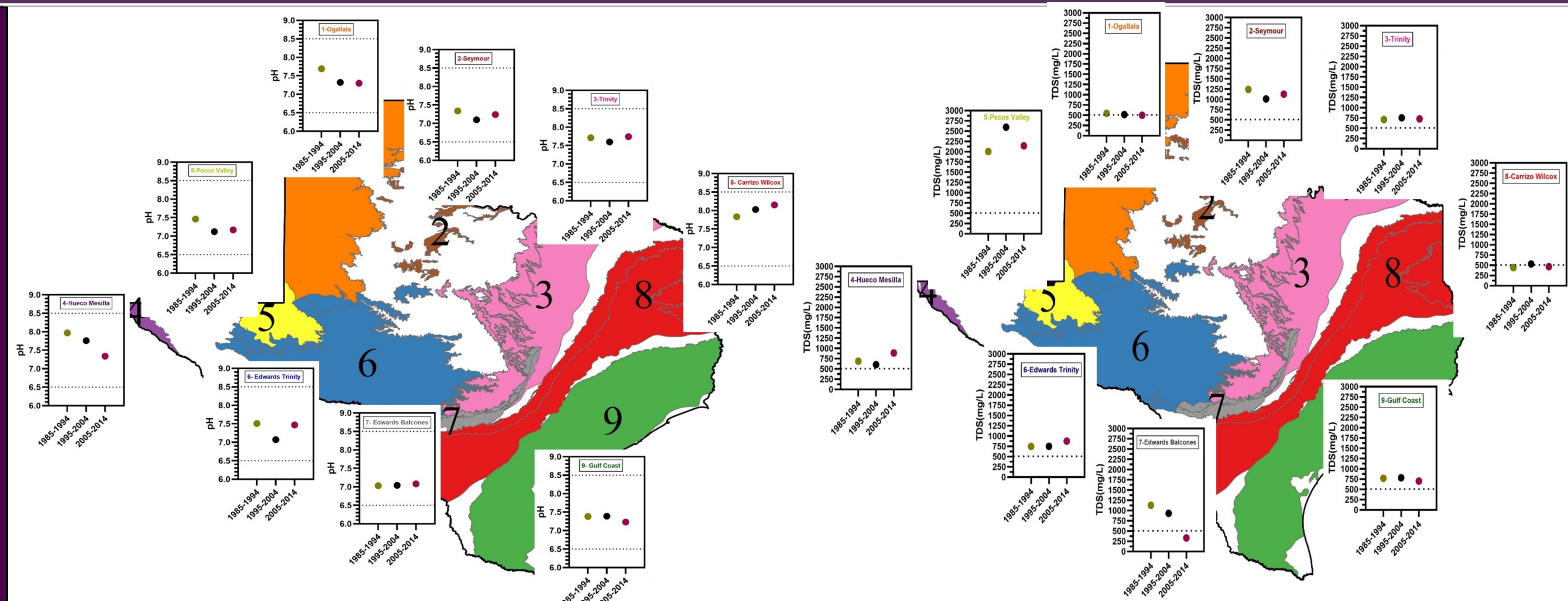
Logistic Modeling

$$y = \sum_{n=1}^n \frac{C_n}{1 + e^{-a_n(x-x_n)}}$$

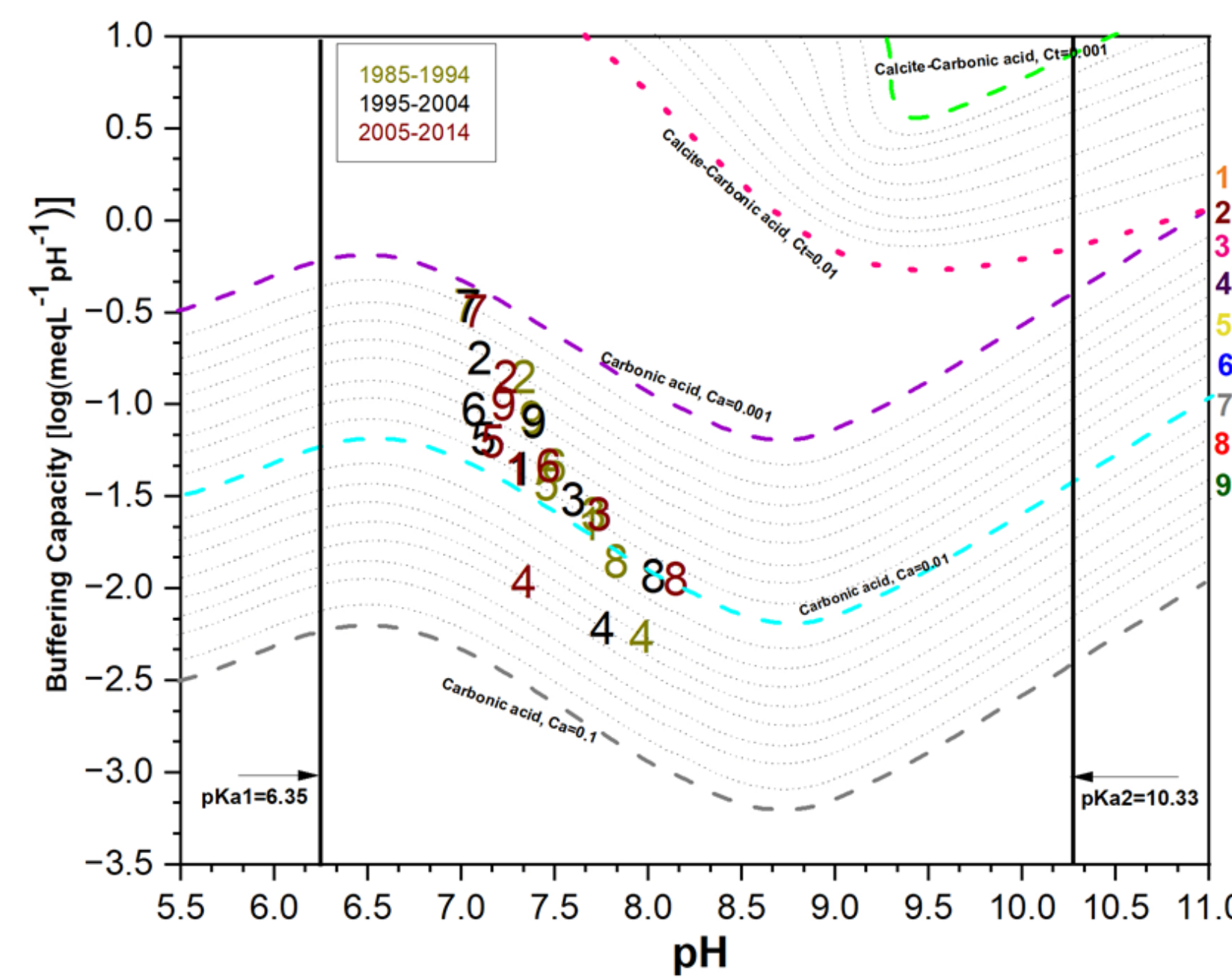
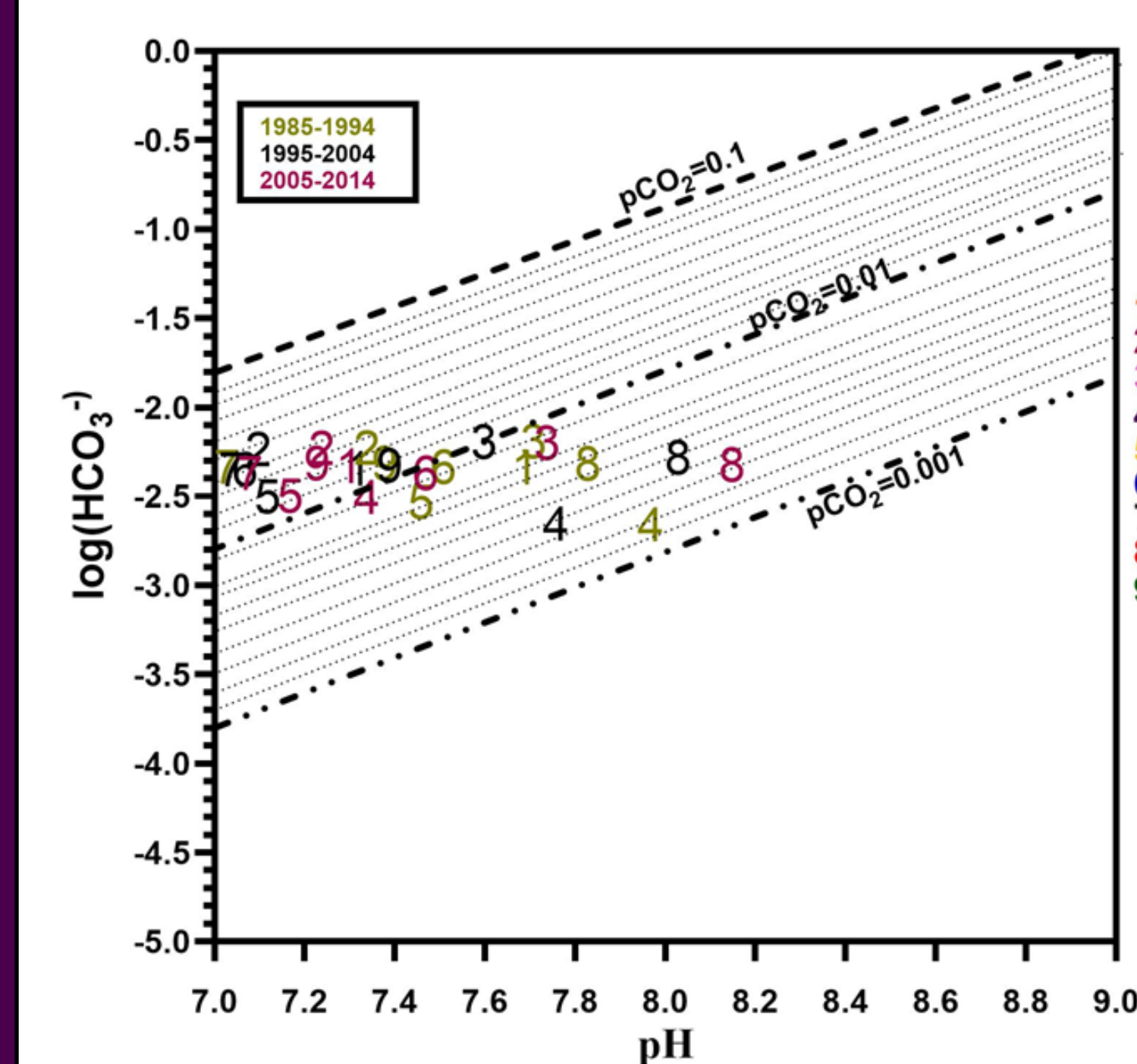
- C_n = Magnitude of the subpopulation component
- X_n = Median value within the subpopulation
- n = Total number of subpopulations.
- y = Cumulative frequency (%)
- a_n = variability around the mean
- x = Observed value of the population



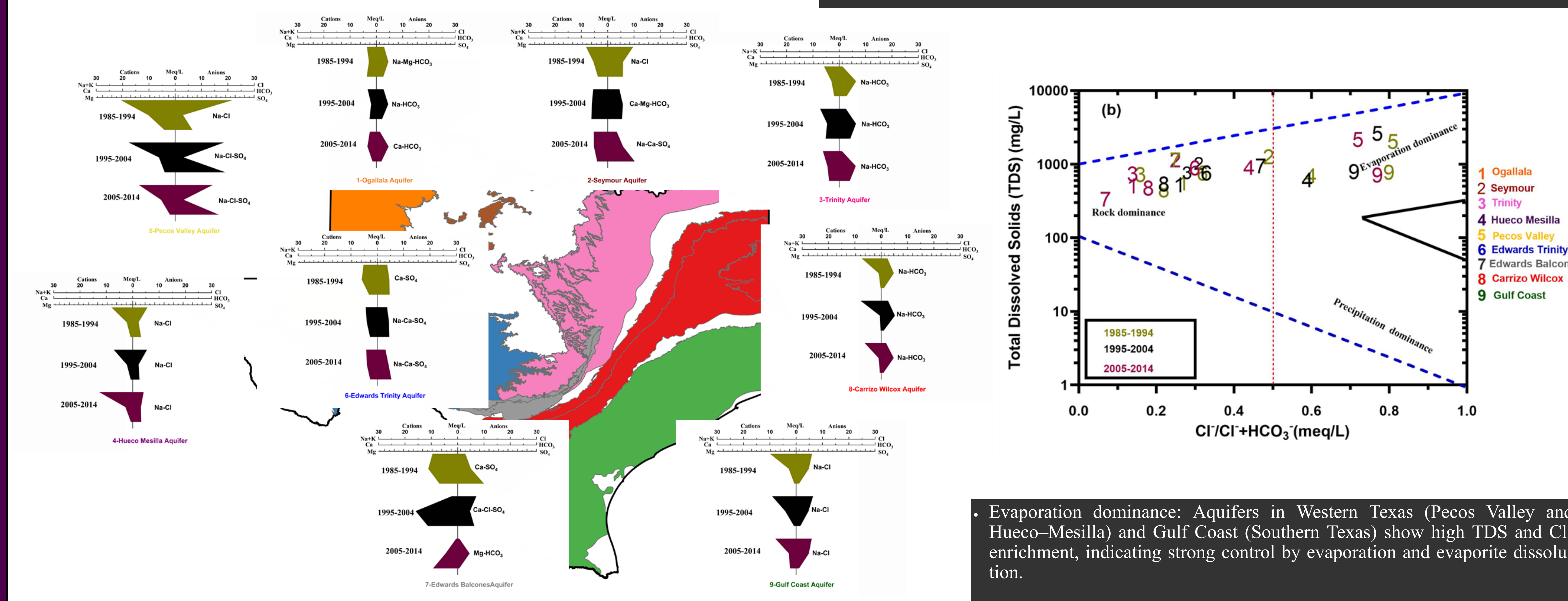
RESULTS AND DISCUSSION



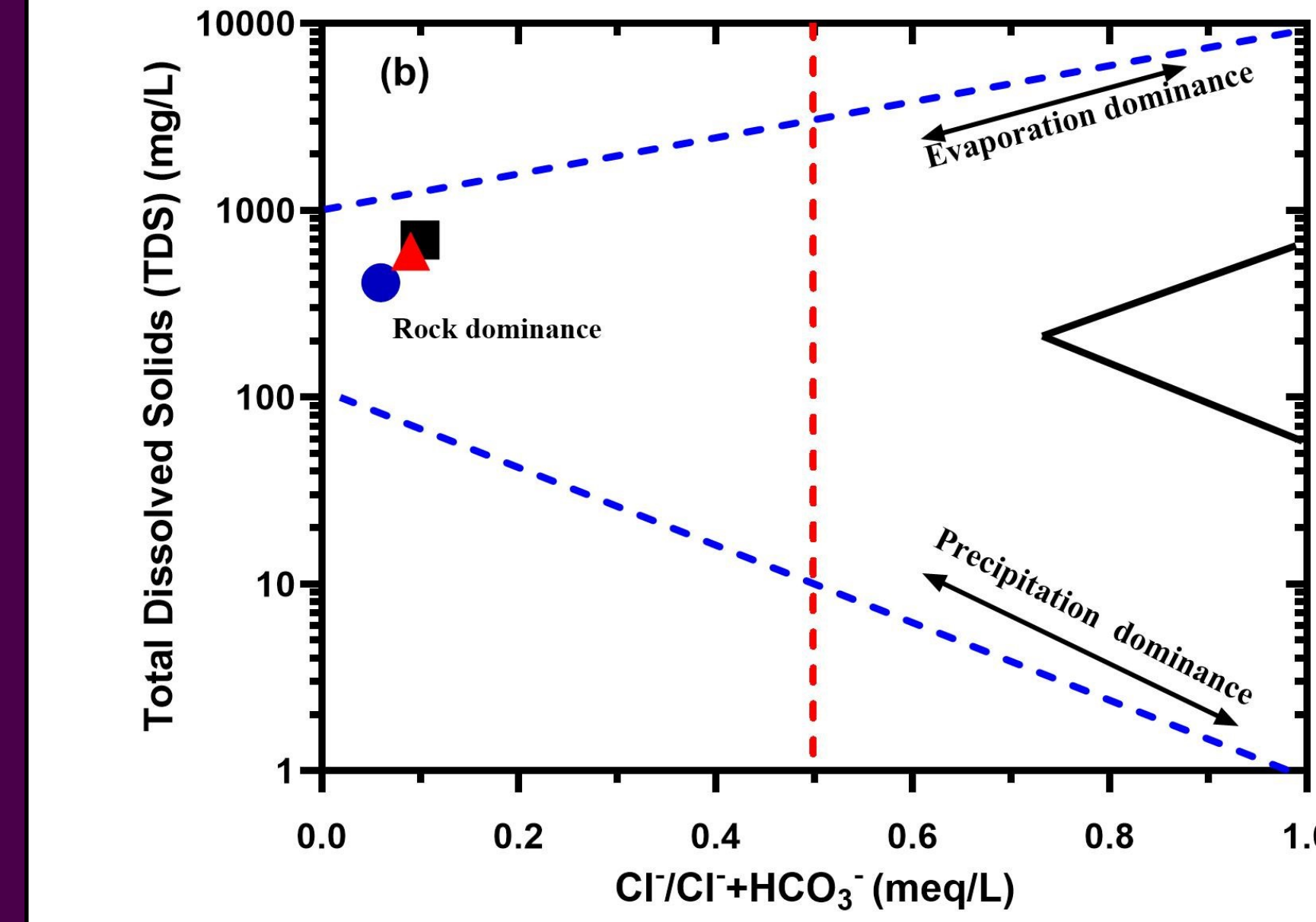
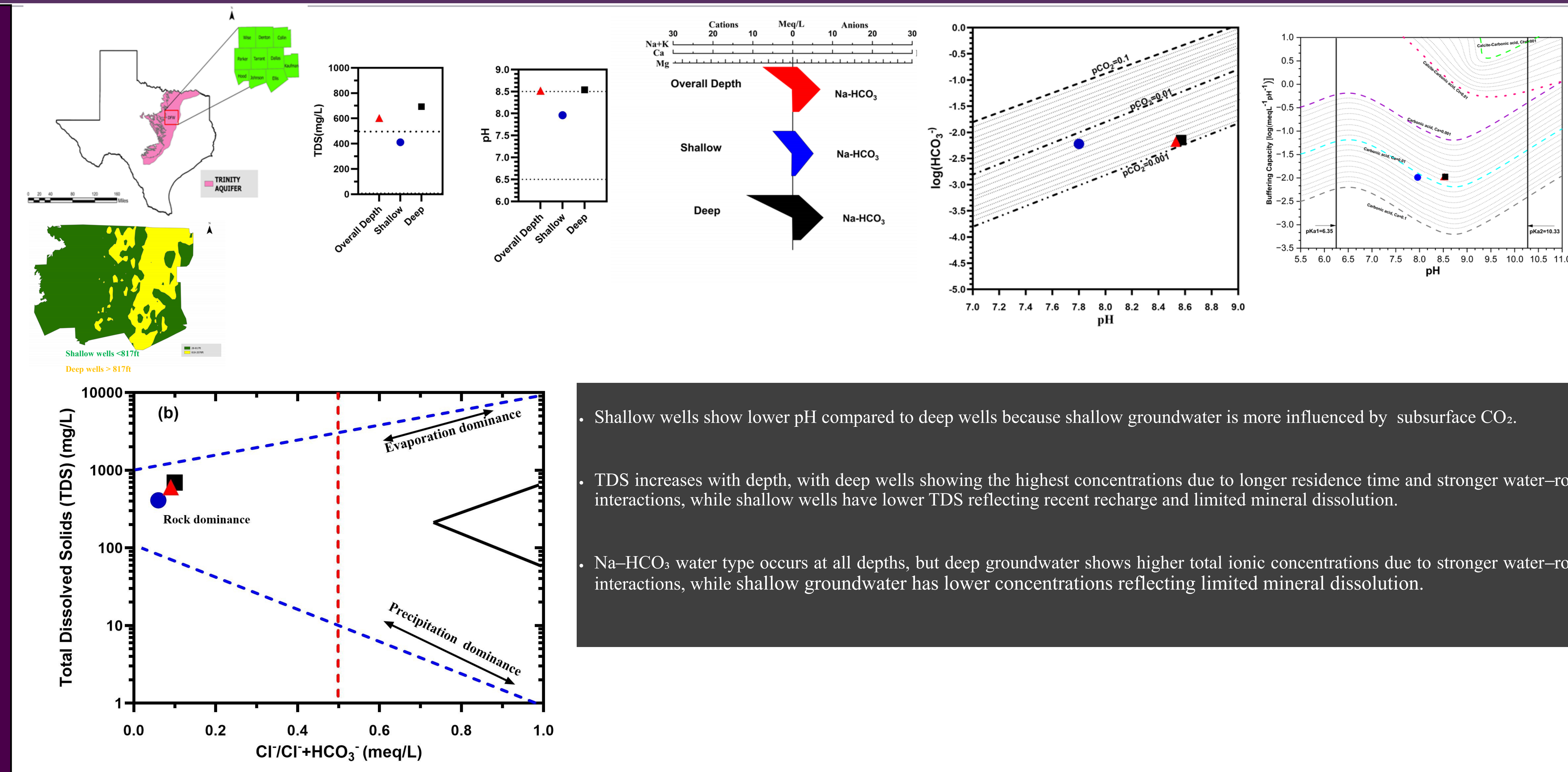
- Western and North-Central Texas aquifers: pH generally declined during the first two decades, but the Hueco-Mesilla aquifers decline in the most recent decade.
- Southern Texas aquifers: pH generally increased over the three decades, although the Gulf Coast Aquifer shows a decline in the last decade.
- Western Texas aquifers: TDS shows a consistent increase across the decades with Pecos Valley showing a decrease in the last decade.
- North-central and Southern Texas aquifers: TDS generally decreases over the same period.



- Increased in partial pressure of CO₂ (pCO₂) in groundwater produces carbonic acid, where higher pCO₂ increases carbonic acid formation and lowers pH.
- Edwards Balcones exhibits slightly higher buffering than Seymour, reflecting stronger carbonate control and greater bicarbonate availability in this limestone-dominated aquifer allowing groundwater to resist pH changes and maintain stable hydrogeochemical conditions.



- Stable Groundwater types:** The Trinity, Carrizo-Wilcox, Gulf Coast and Hueco Mesilla aquifers maintain consistent groundwater type across decades.
- Variable Groundwater types:** The Ogallala, Seymour, Pecos Valley, Edwards Balcones and Edwards Trinity aquifers exhibit shifts in groundwater type across the decades.



- Shallow wells show lower pH compared to deep wells because shallow groundwater is more influenced by subsurface CO₂.
- TDS increases with depth, with deep wells showing the highest concentrations due to longer residence time and stronger water-rock interactions, while shallow wells have lower TDS reflecting recent recharge and limited mineral dissolution.
- Na-HCO₃ water type occurs at all depths, but deep groundwater shows higher total ionic concentrations due to stronger water-rock interactions, while shallow groundwater has lower concentrations reflecting limited mineral dissolution.

CORRELATION MATRIX

Spearman rank correlation between pH, Hydrogeochemical parameters and environmental parameters across the nine major aquifers of Texas.

Parameter	Spearman ρ	p-value
Precipitation	-0.72	0.04
Buffering Capacity	0.85	0.01
Partial Pressure	0.85	0.01

Spearman rank correlation showing the relationship between pH, Hydrogeochemical parameters and environmental parameters across the 10 counties of the Trinity Aquifer.

Parameter	Spearman ρ	p-value
TDS	0.93	0.001
Partial Pressure (CO ₂)	0.96	0.0001
Buffering Capacity	0.88	0.003

- Weak hydrochemical controls on pH: Spearman correlation results indicate that TDS, population, and land use show no statistically significant relationship with pH across the nine major Texas aquifers (p > 0.05).

- This suggests that pH variability is primarily governed by intrinsic geochemical processes such as carbonate buffering, subsurface CO₂ dynamics and precipitation.

- Dominant controls on pH in the DFW metropolplex: Within the ten-county DFW region, land use shows no significant correlation with pH (p > 0.05), indicating limited direct anthropogenic influence on pH.

- In contrast, TDS, partial pressure of CO₂ (pCO₂), and buffering capacity exhibit significant relationships with pH, highlighting that groundwater pH is primarily controlled by geochemical processes including carbonate buffering, subsurface CO₂ dynamics rather than land-use change.

CONCLUSION

- Groundwater chemistry across Texas aquifers (1985–2014) shows declining pH linked to increasing pCO₂ and carbonic acid formation, and variable TDS influenced by lithology, residence time, and recharge.
- Carbonate buffering plays a key role in regulating pH, with limestone-rich aquifers (Edwards Balcones aquifer) showing stronger resistance to acidification compared to other systems.
- Hydrochemical facies indicate dominant control by natural processes, particularly rock weathering (silicate, carbonate, evaporite) and evaporation across different aquifers.
- In the Trinity Aquifer (DFW, 2015–2024), groundwater exhibits clear depth-dependent evolution, where shallow wells are recharge-driven and CO₂-influenced, while deep wells show higher pH, stronger buffering, and greater mineralization.
- Despite rapid urbanization, groundwater chemistry is primarily controlled by natural hydrogeochemical processes, with anthropogenic influences playing a secondary role.

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