

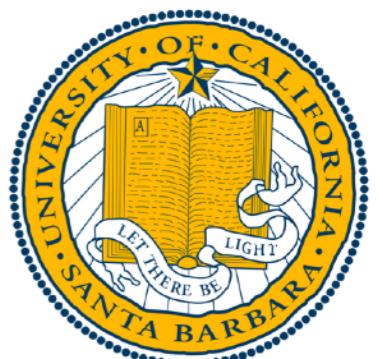
# The Disproportionate Effects of Drought on Drinking Water Quality: Evidence from California

Sandy Sum

Bren School of Environmental Science and Management  
Department of Economics

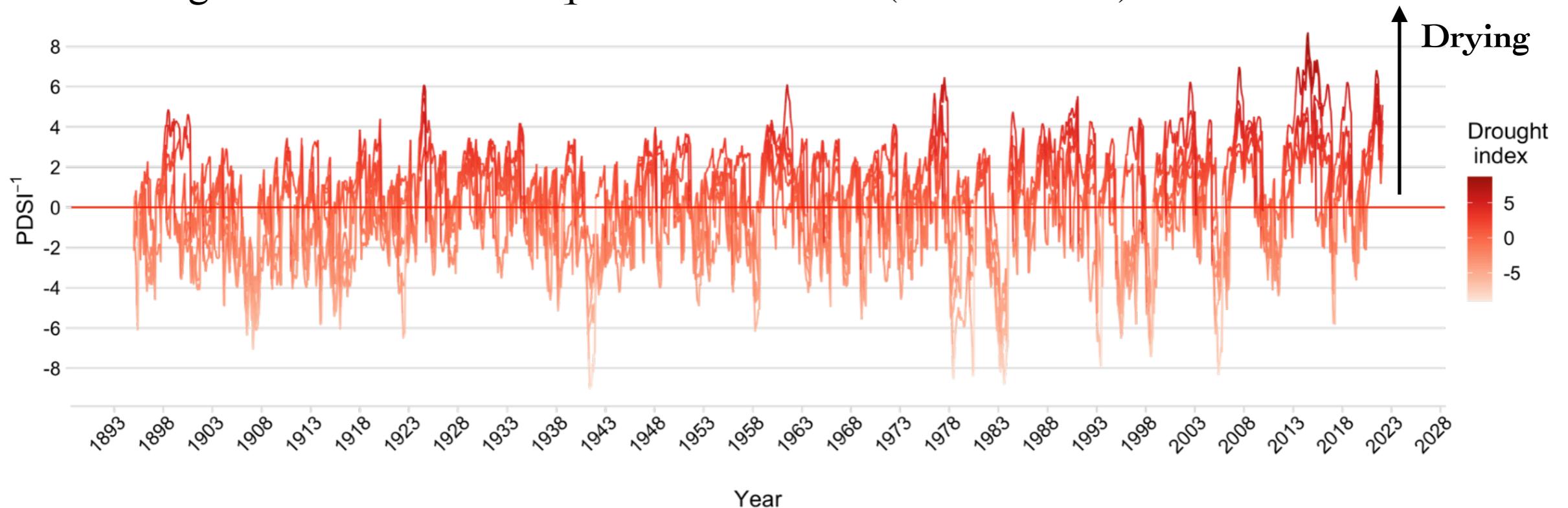
University of California, Santa Barbara

May 9, 2024



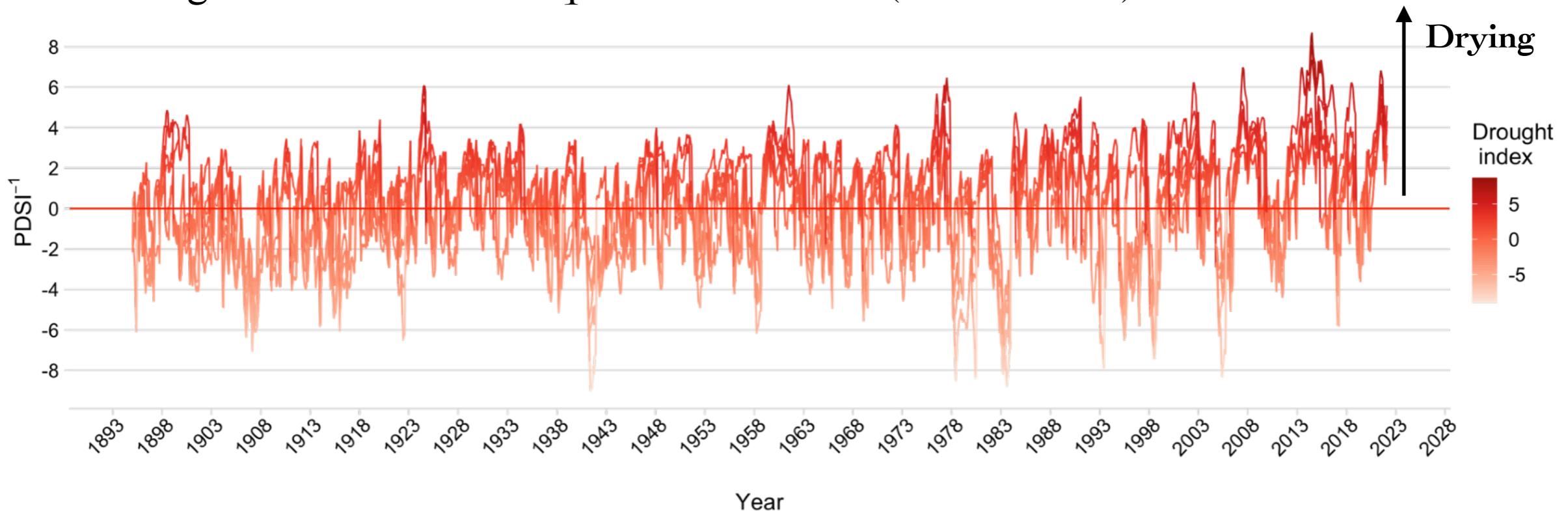
# Motivation

- ▶ Drought is a prolonged period of abnormally low rainfall, frequently compounded by high temperature
- ▶ Drought will be more frequent and severe (IPCC, 2021)



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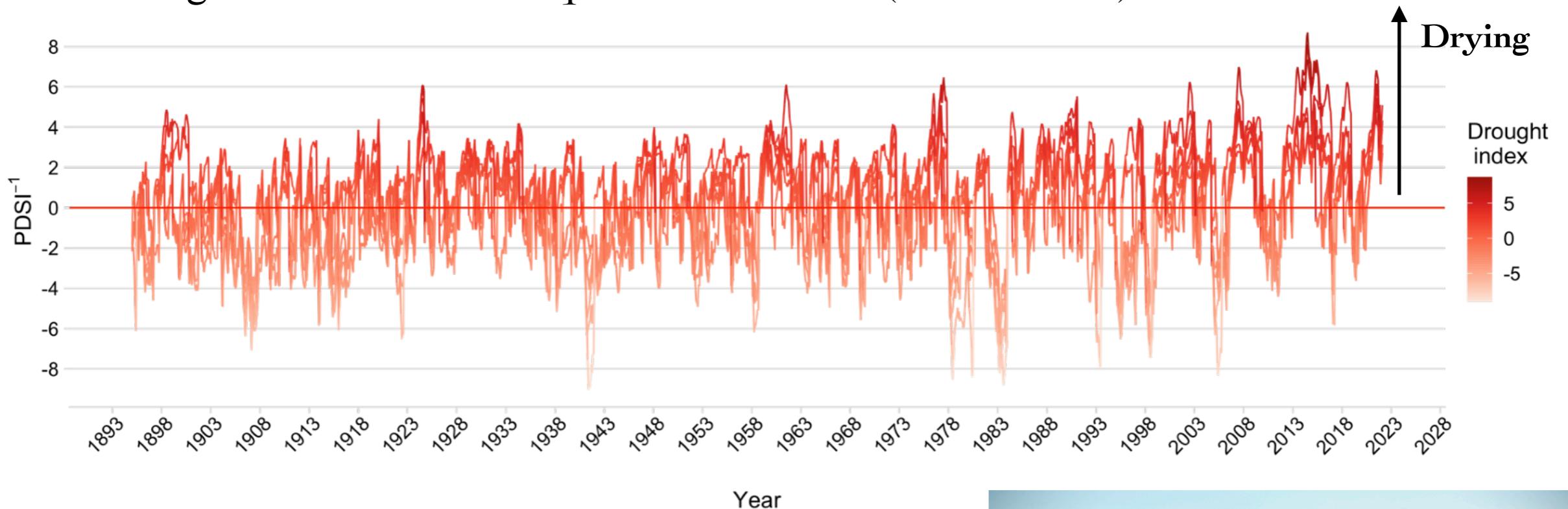
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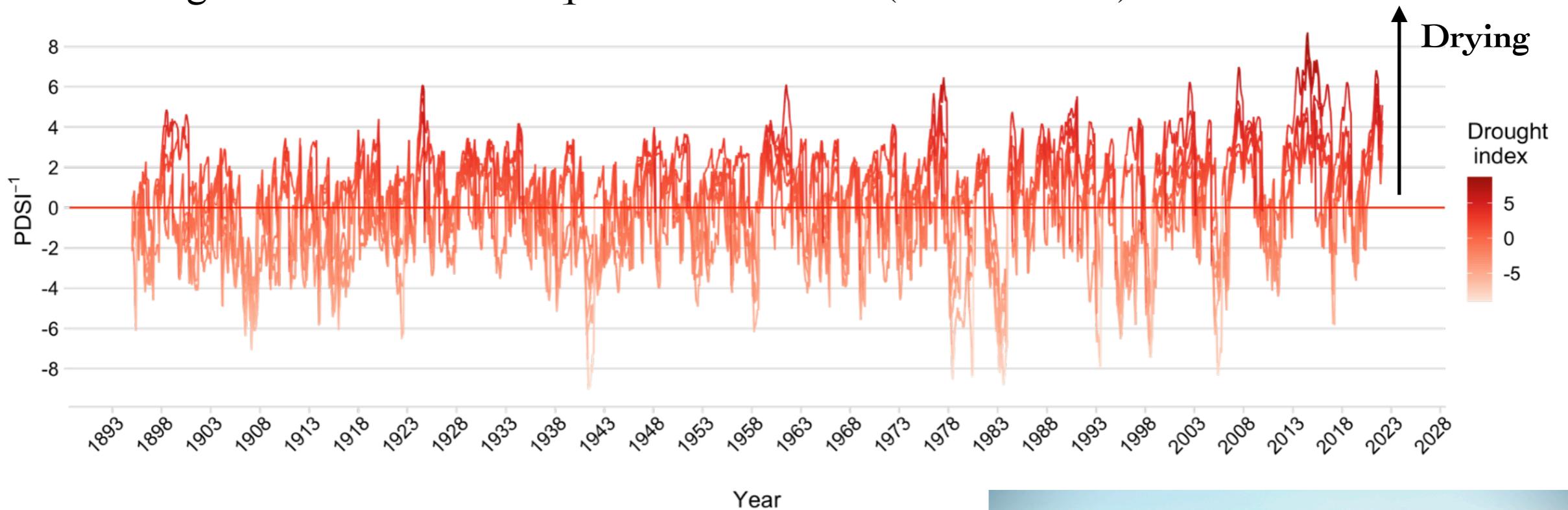


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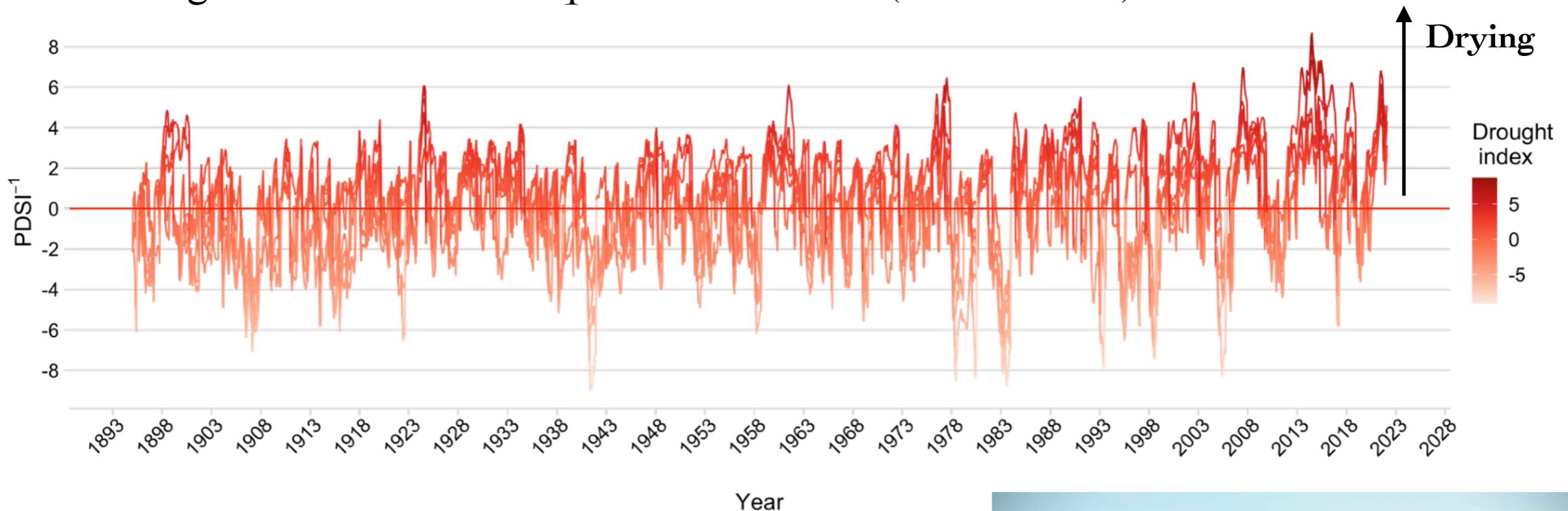


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  - Water shortages → agricultural losses and domestic water supply disruptions



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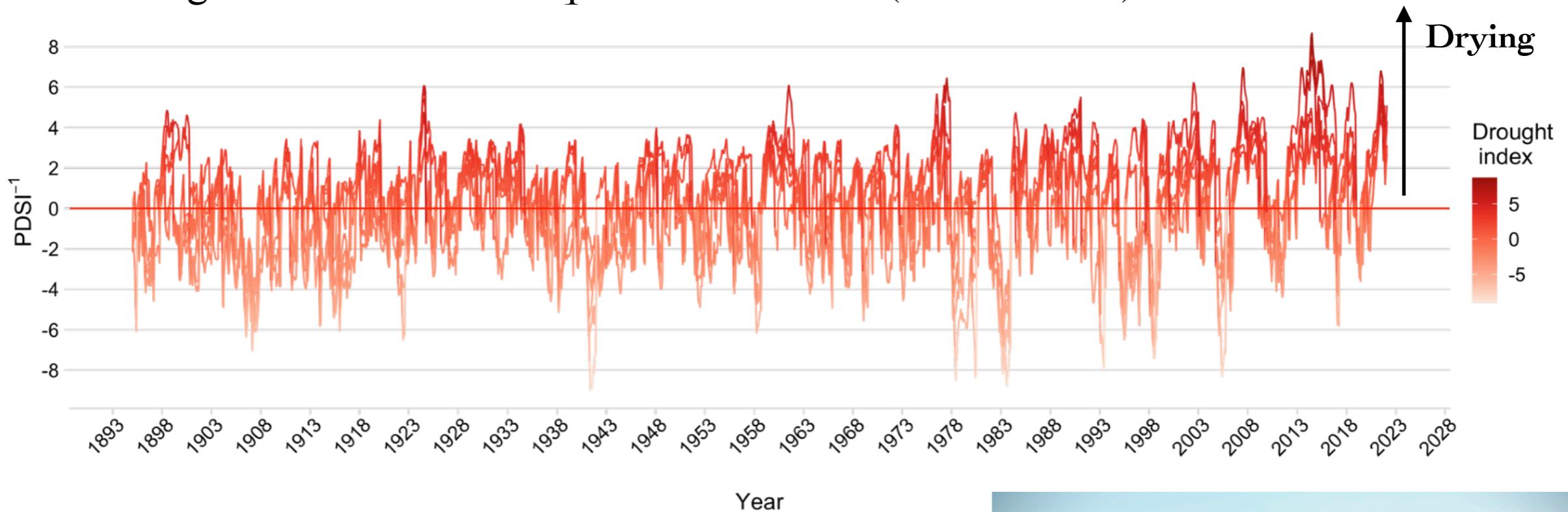


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  - Water shortages → agricultural losses and domestic water supply disruptions
  - Heat related health and socioeconomic costs
  - **Changes in drinking water quality**



# Defining drinking water quality



Source: Community Water Center

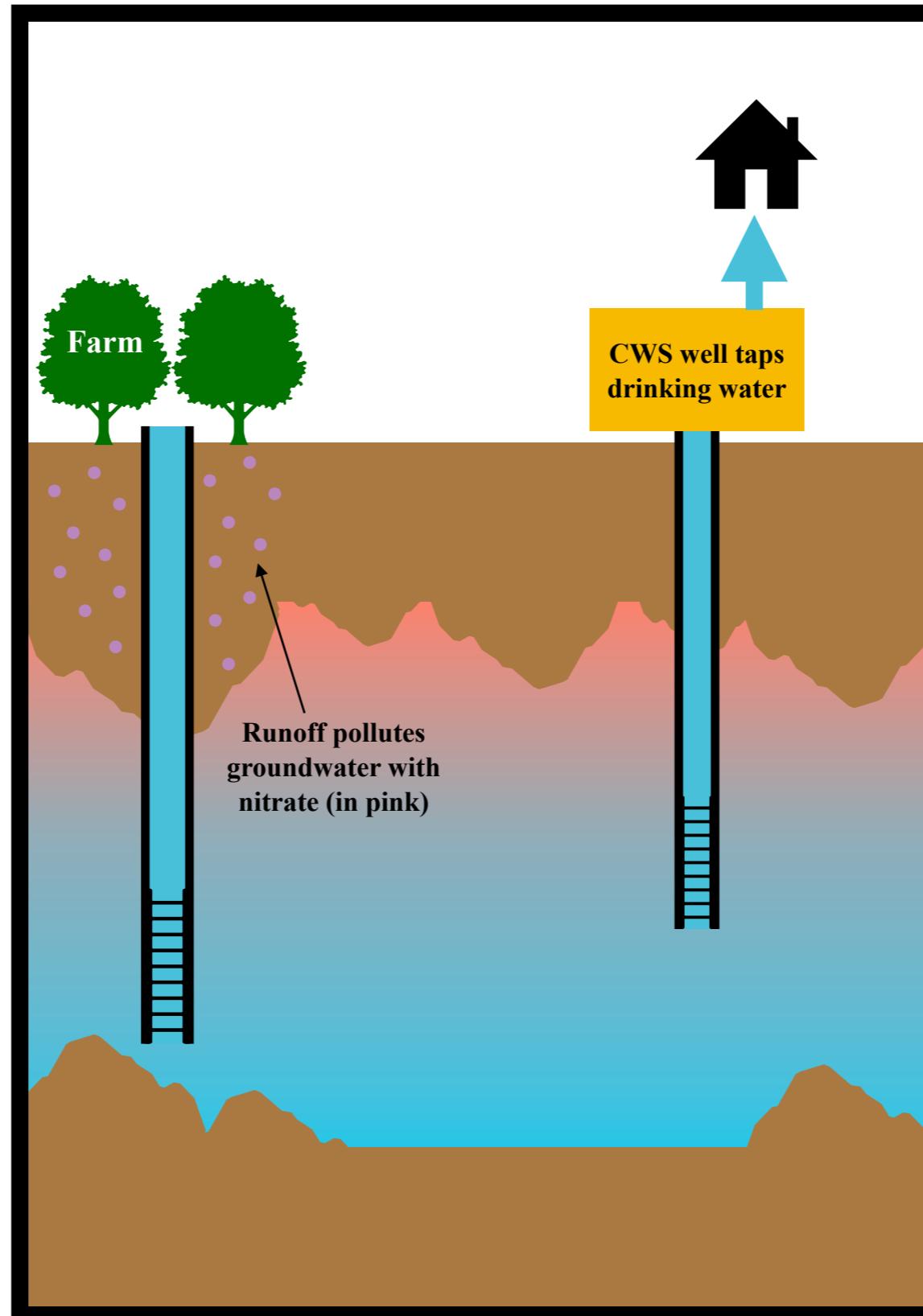
## Nitrates (MCL: 10mg/l)

- ▶ Anthropogenic: 90% from agricultural and waste systems
- ▶ Infant methemoglobinemia; birth defects and developmental outcomes in children; cardiovascular diseases

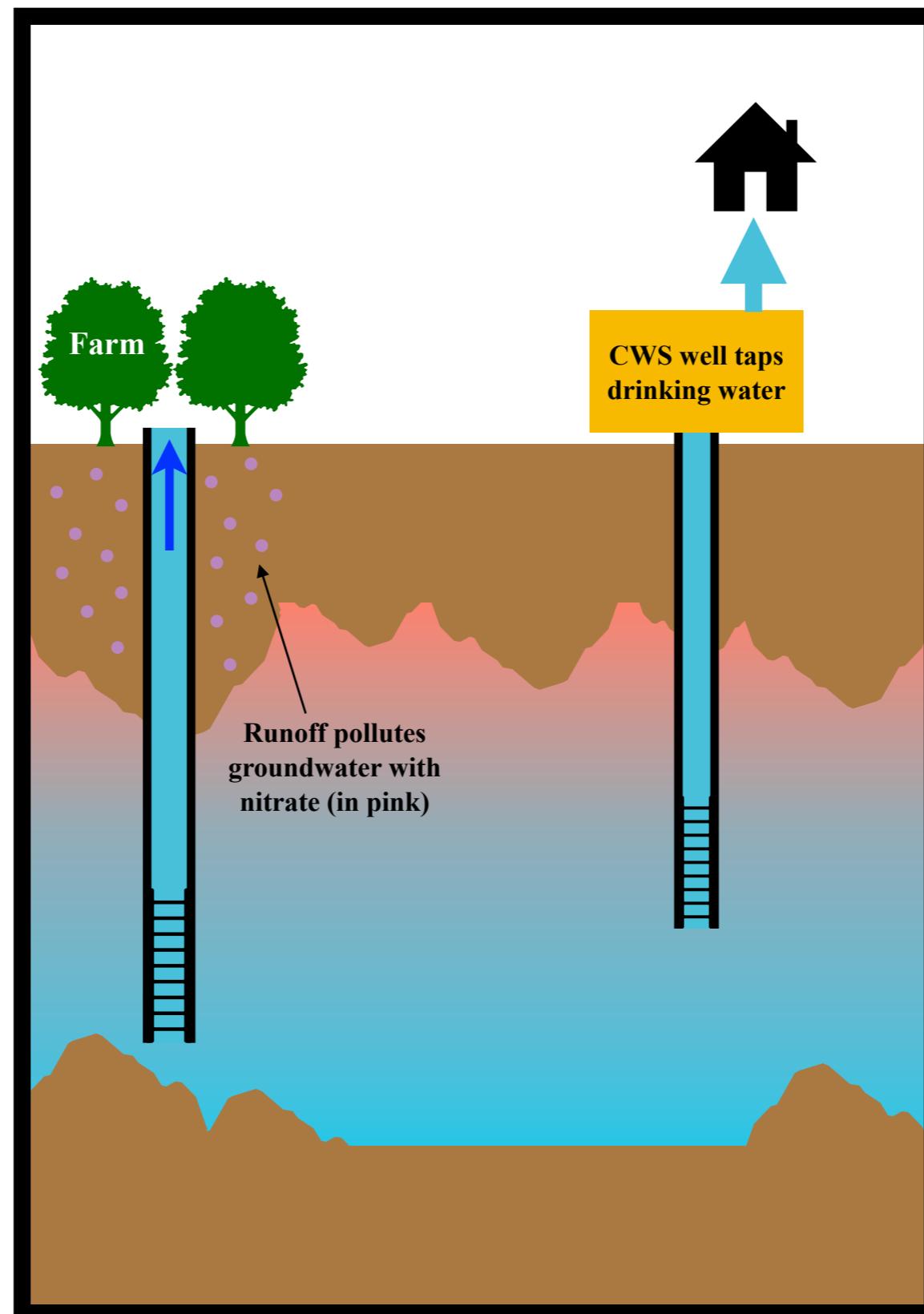
## Arsenic (MCL: 10ug/l)

- ▶ Geogenic: depends on geological and soil properties
- ▶ Skin, lung, bladder cancers; diabetes; high blood pressure

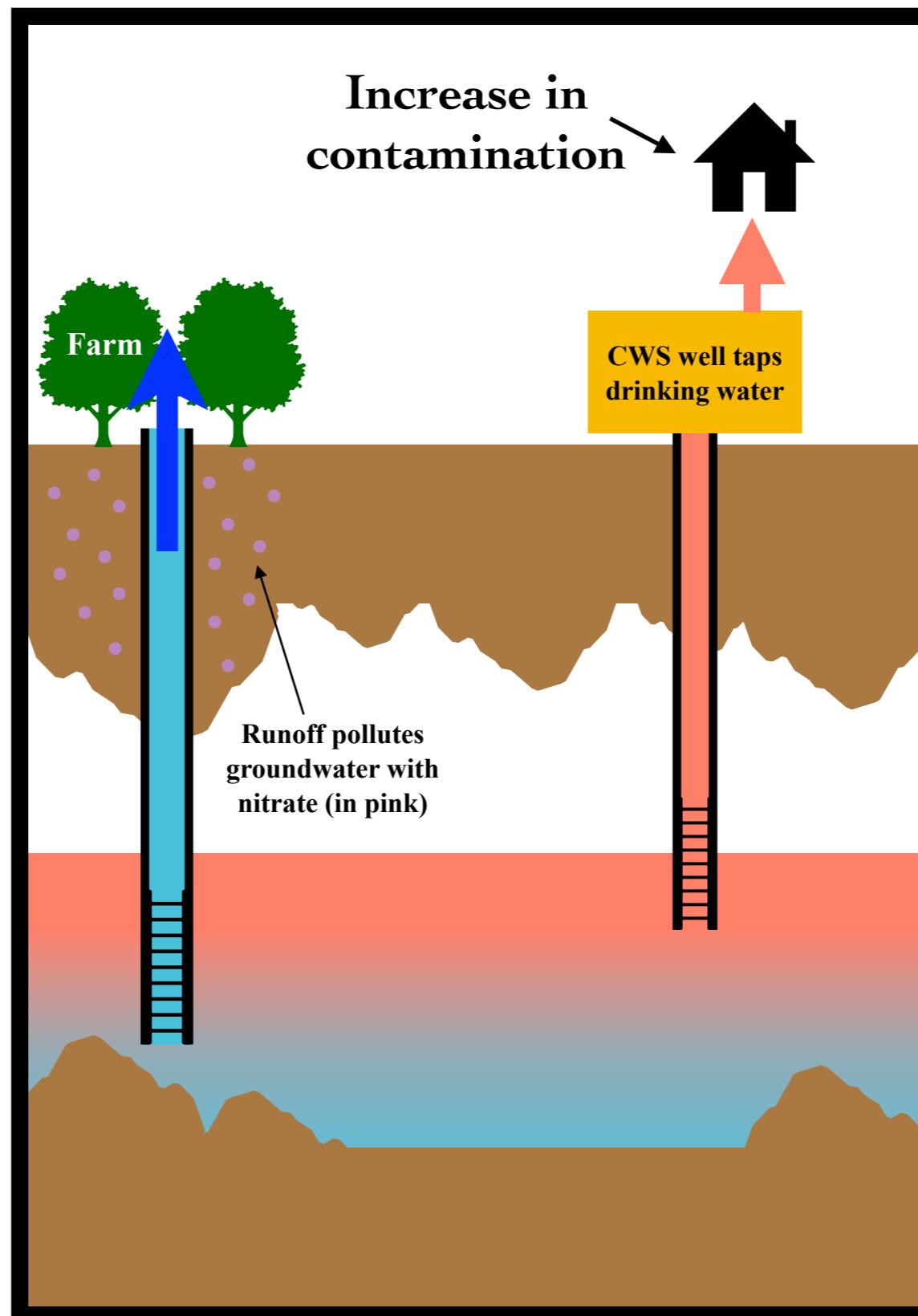
# Drought → groundwater pumping → water contamination



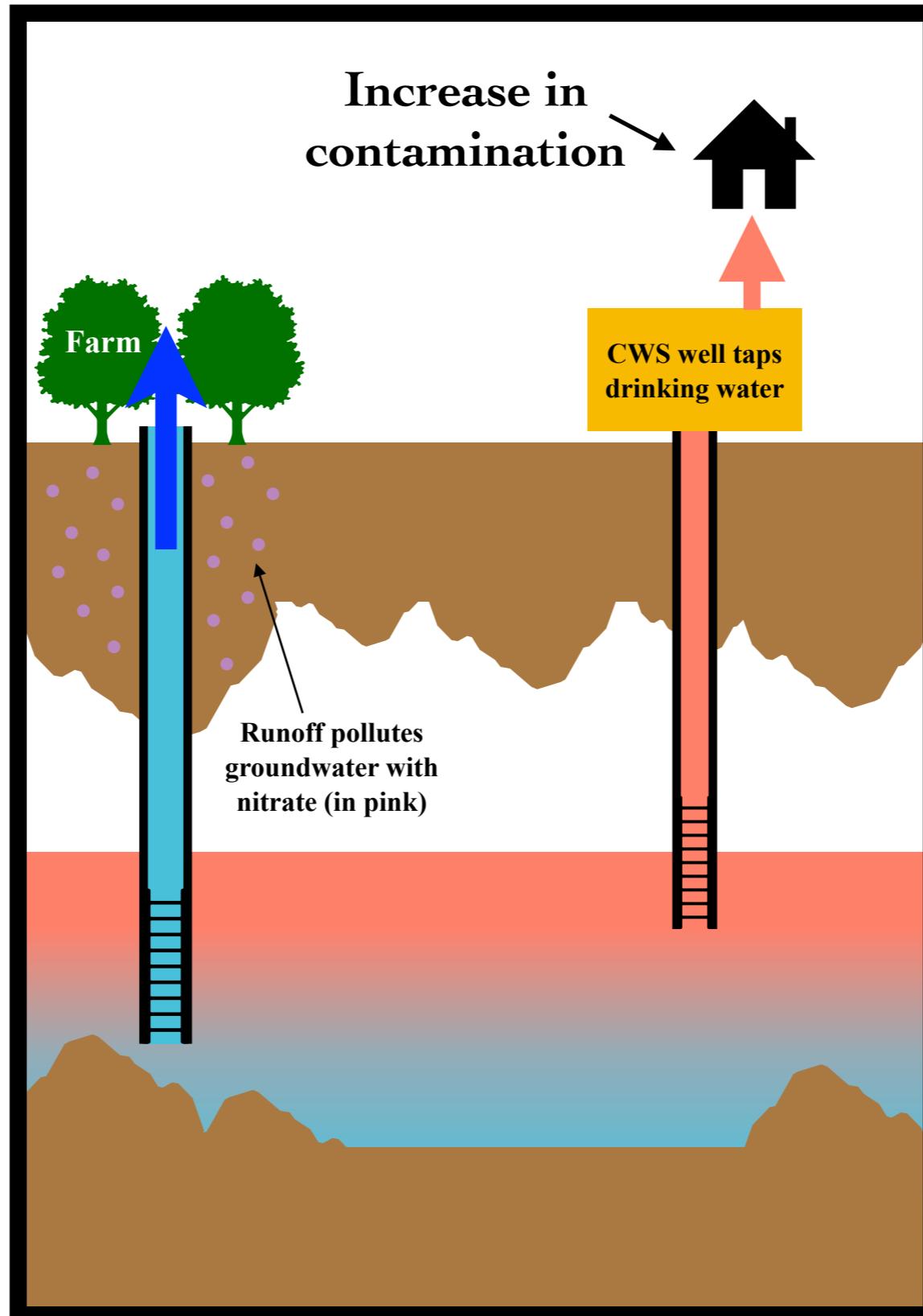
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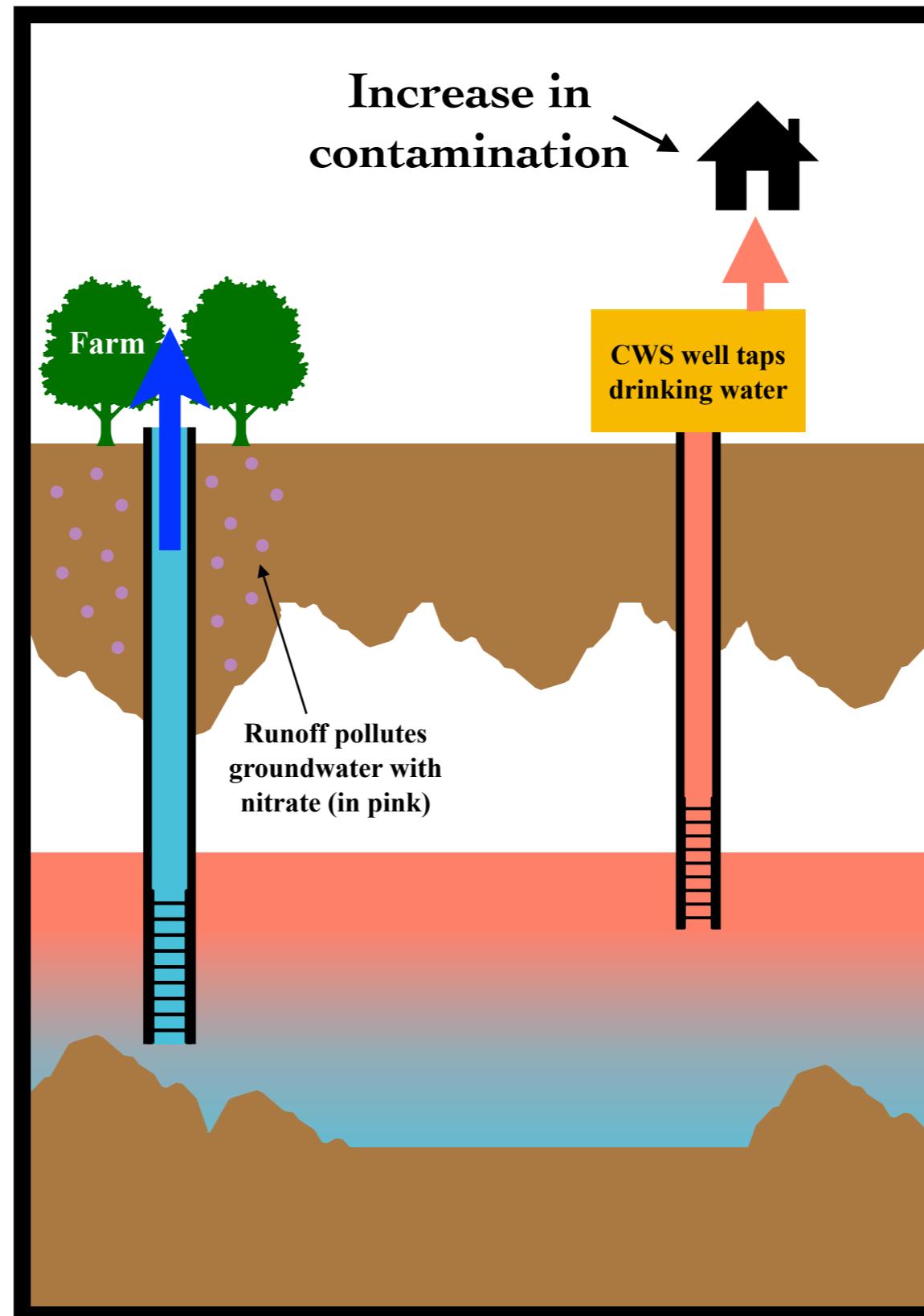
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Land subsides  
→  $\uparrow As$   
 $N \rightarrow \downarrow As$

# Drought → groundwater pumping → water contamination

Common pool resource:  
Pumping not only depletes amount of water for everyone else, it also worsens the quality for users who drink it



Land subsides  
 $\rightarrow \uparrow As$   
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# Mechanisms for drought's impact on surface water quality



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**Temp ↑, As mobilizes and ↑**

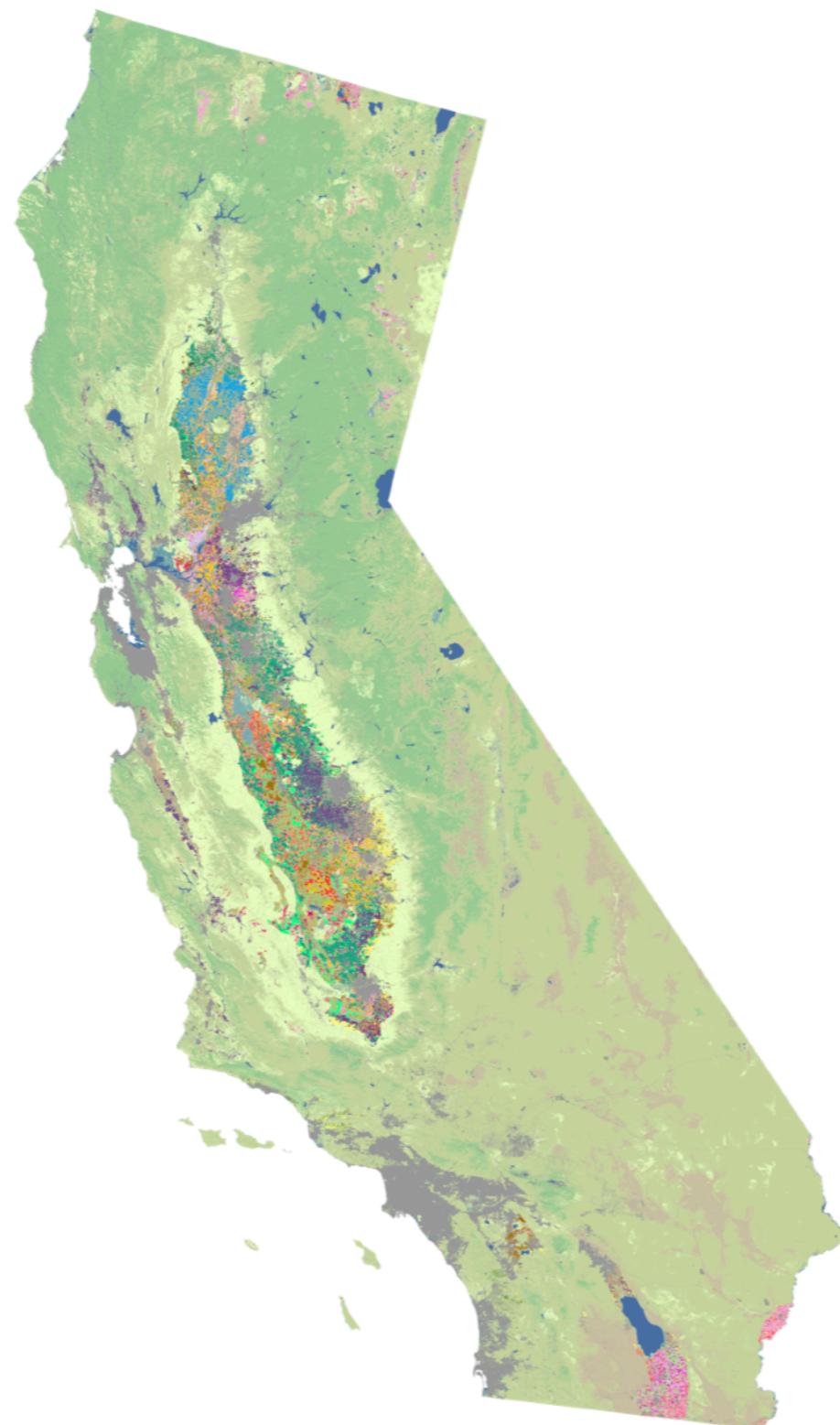
# Mechanisms for drought's impact on surface water quality



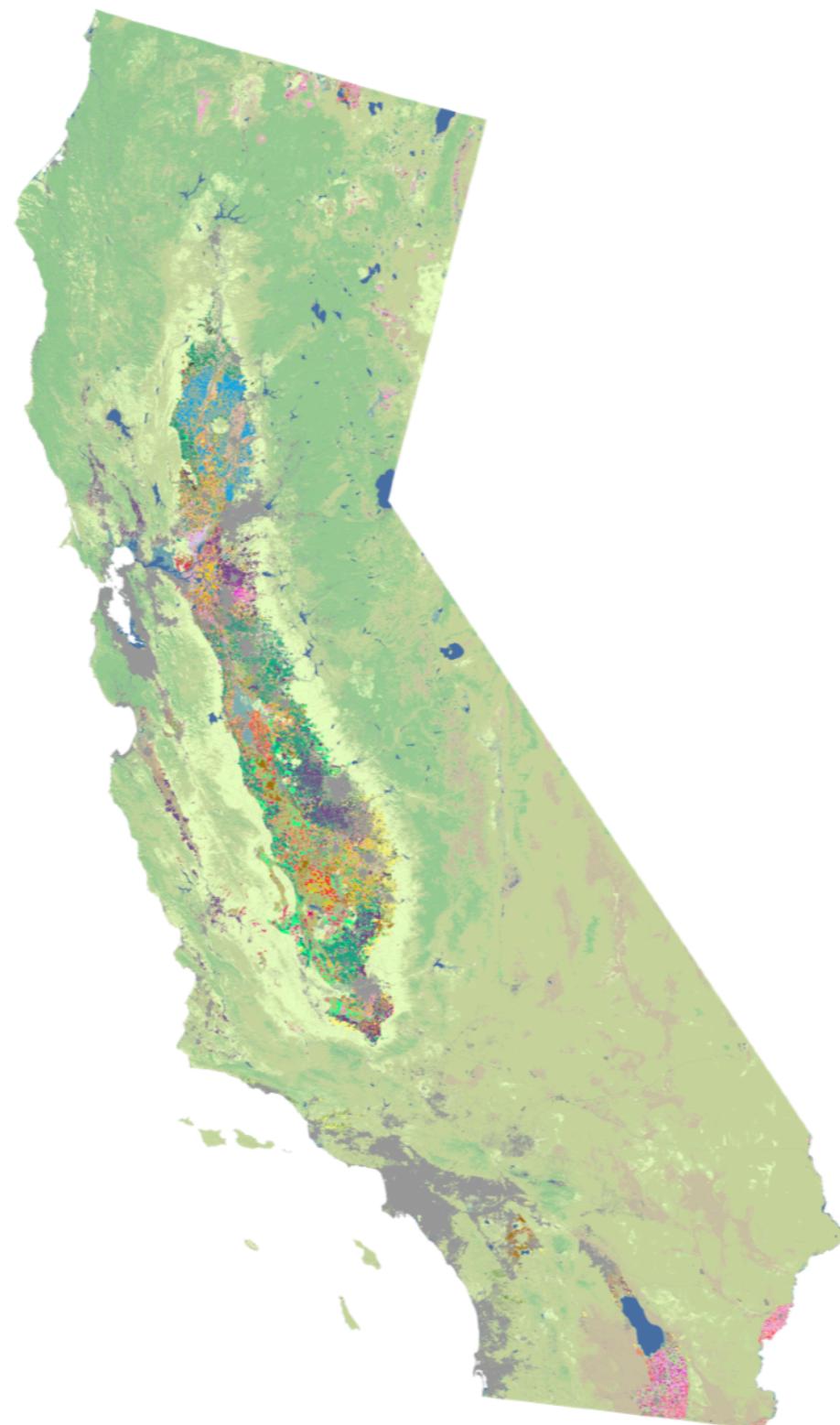
**Temp ↑, As mobilizes and ↑**

**Drop in precipitation also leads to  
increasing concentration of  
contaminants**

# California and drinking water contamination

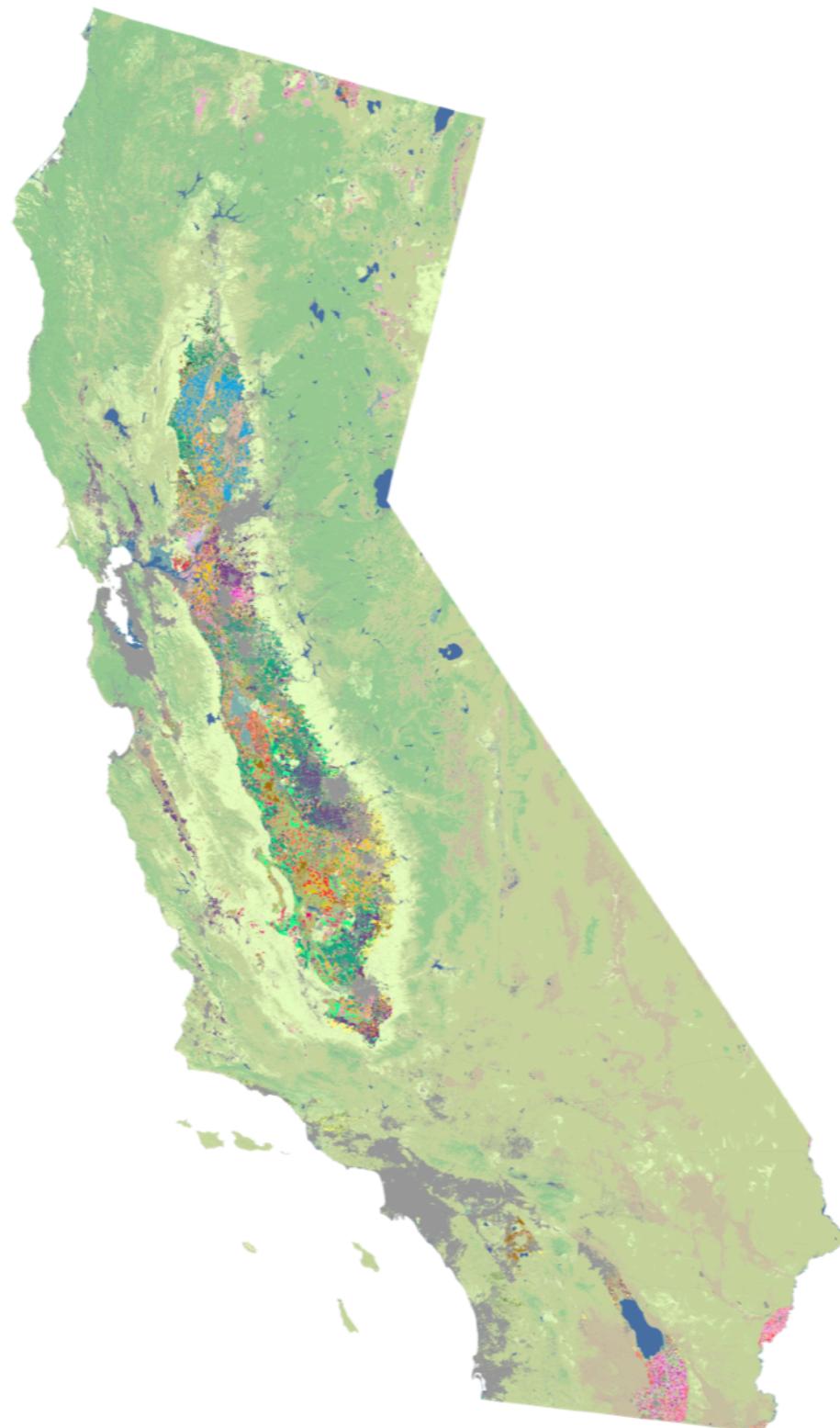


# California and drinking water contamination



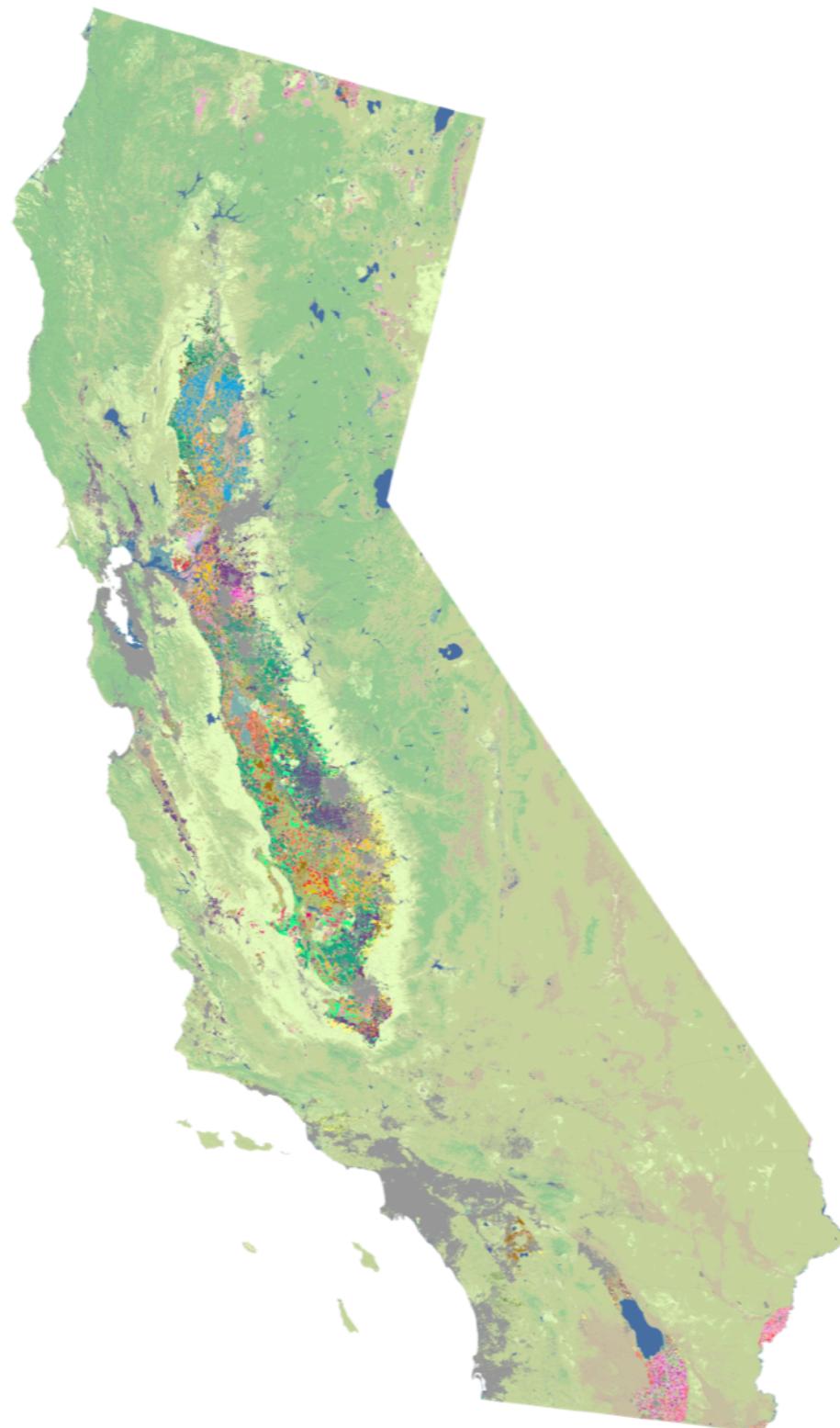
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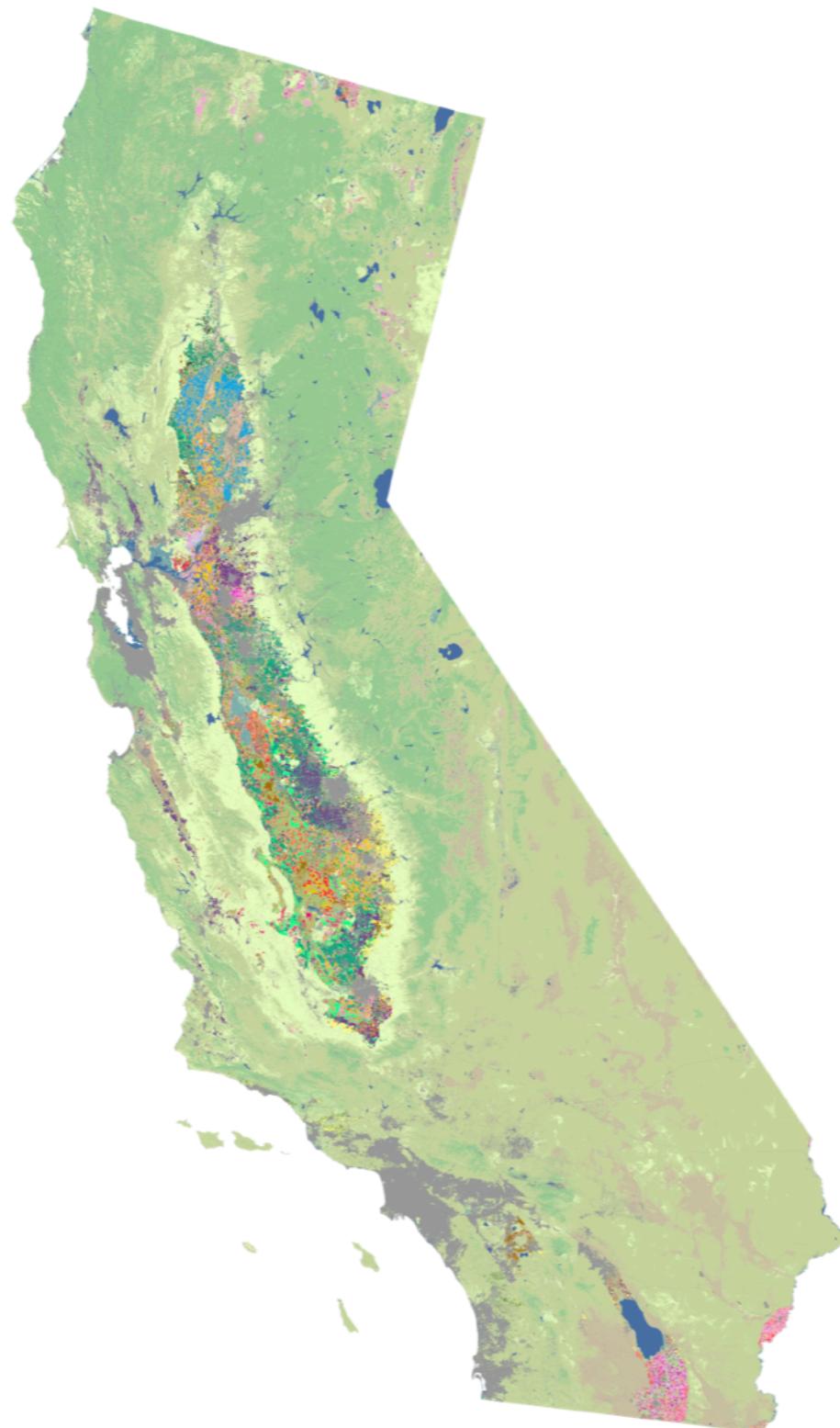
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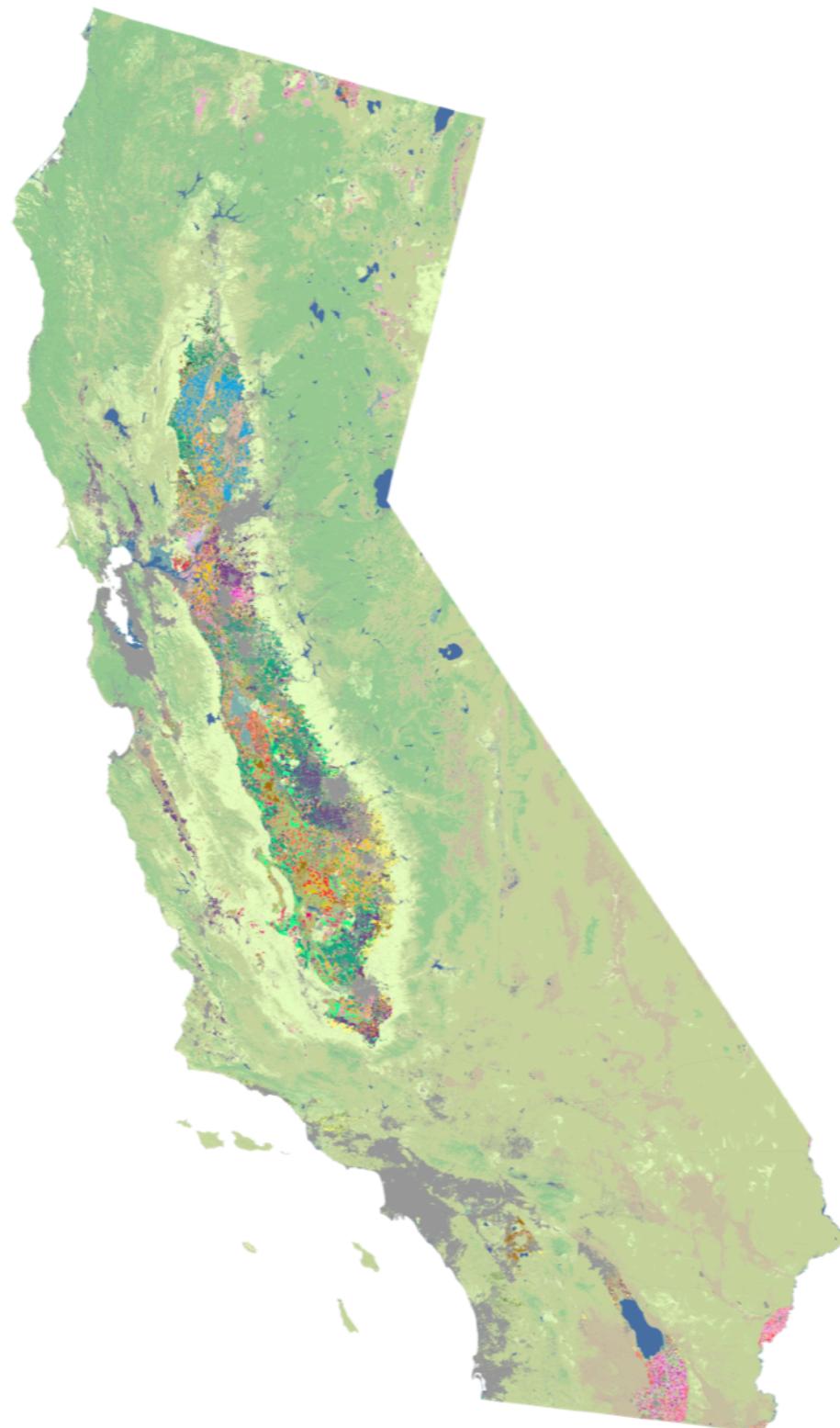
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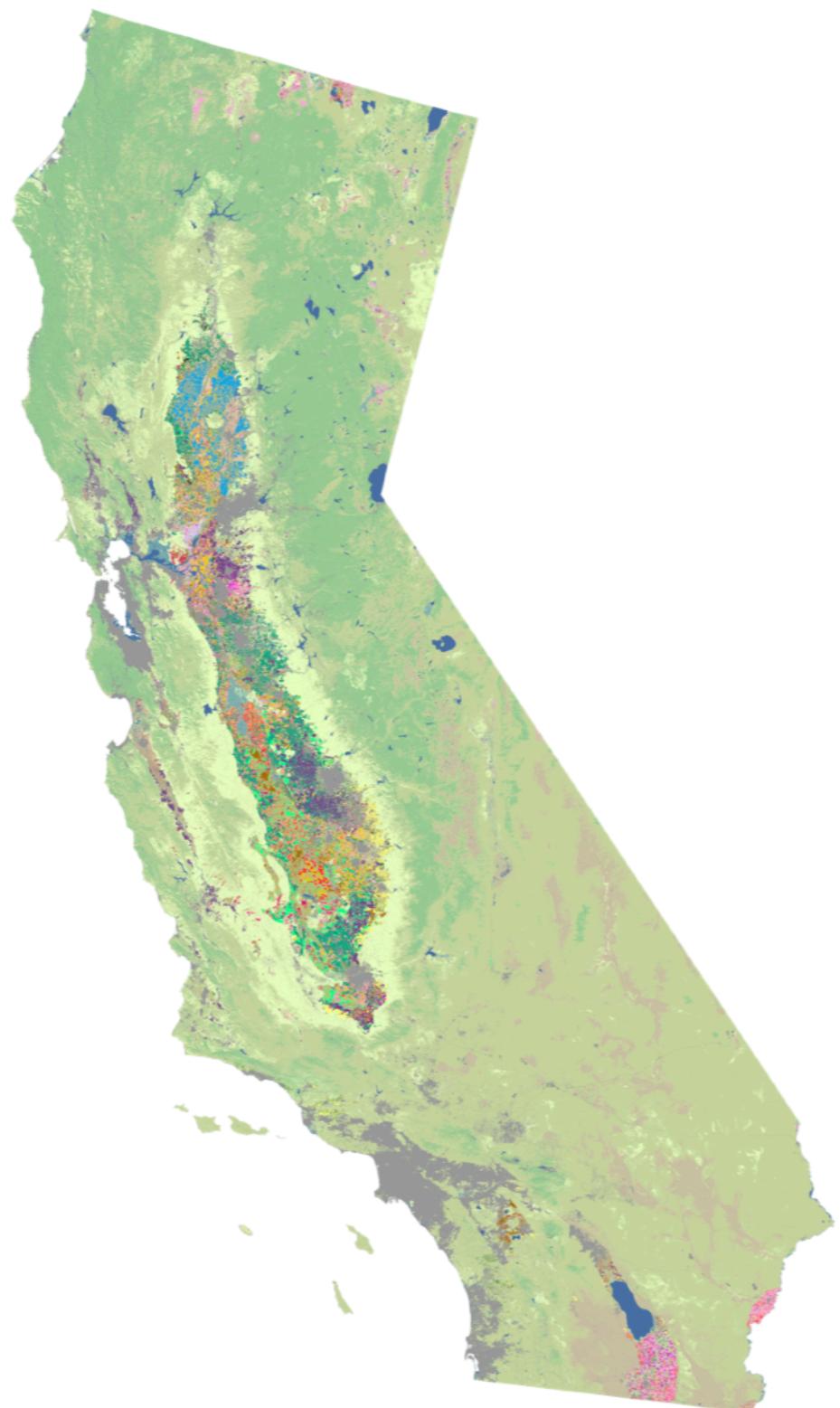
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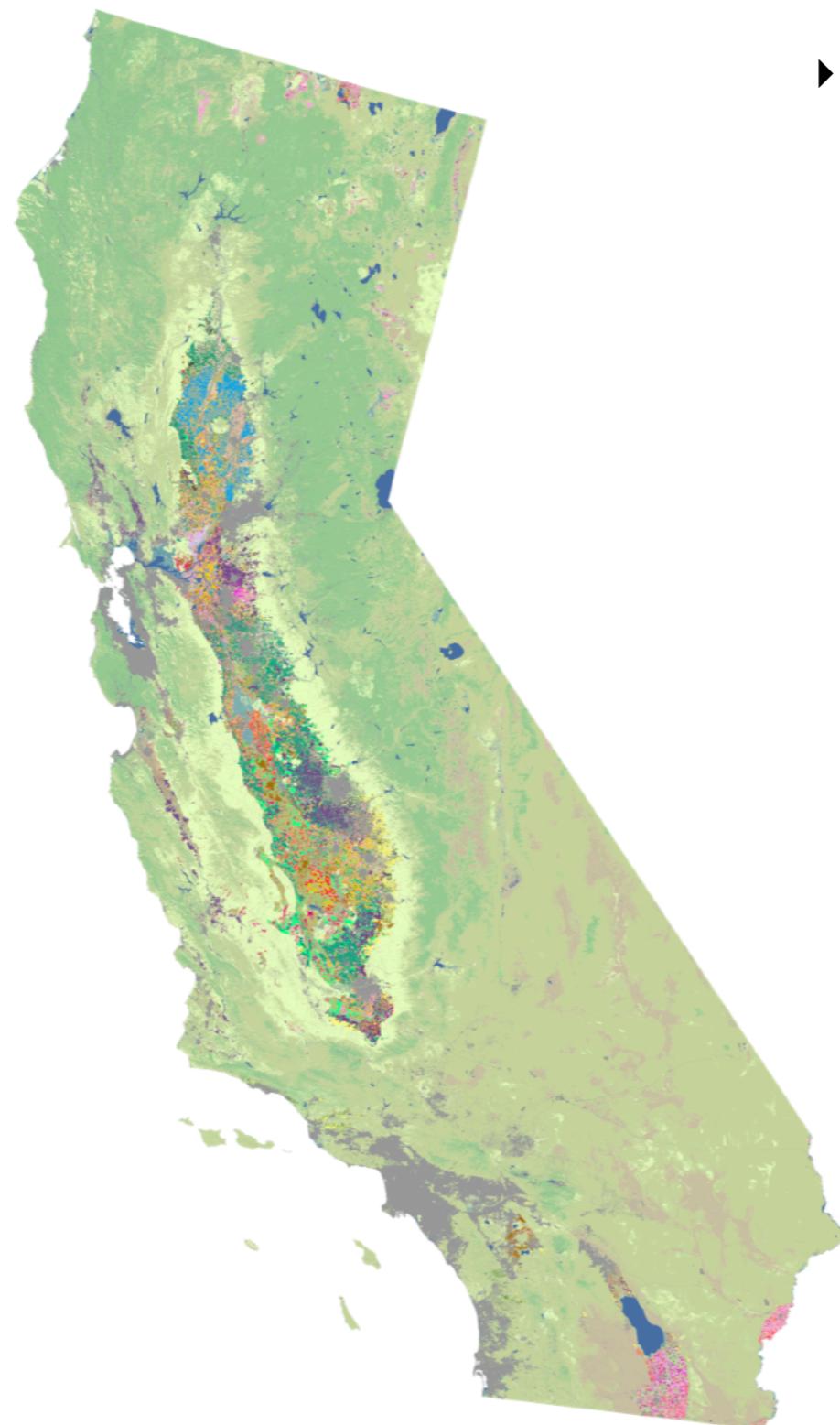


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# Equity implications

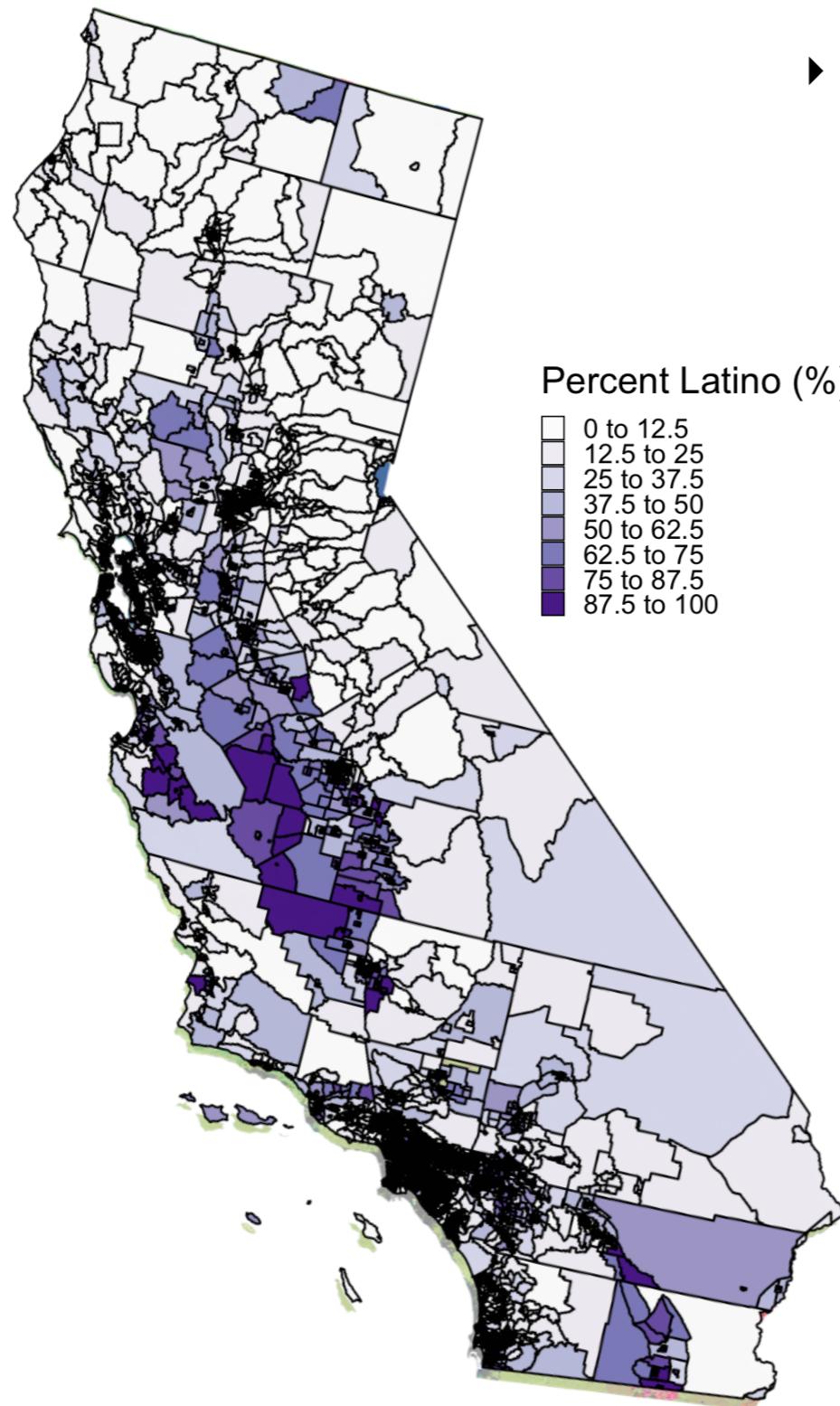


# Equity implications



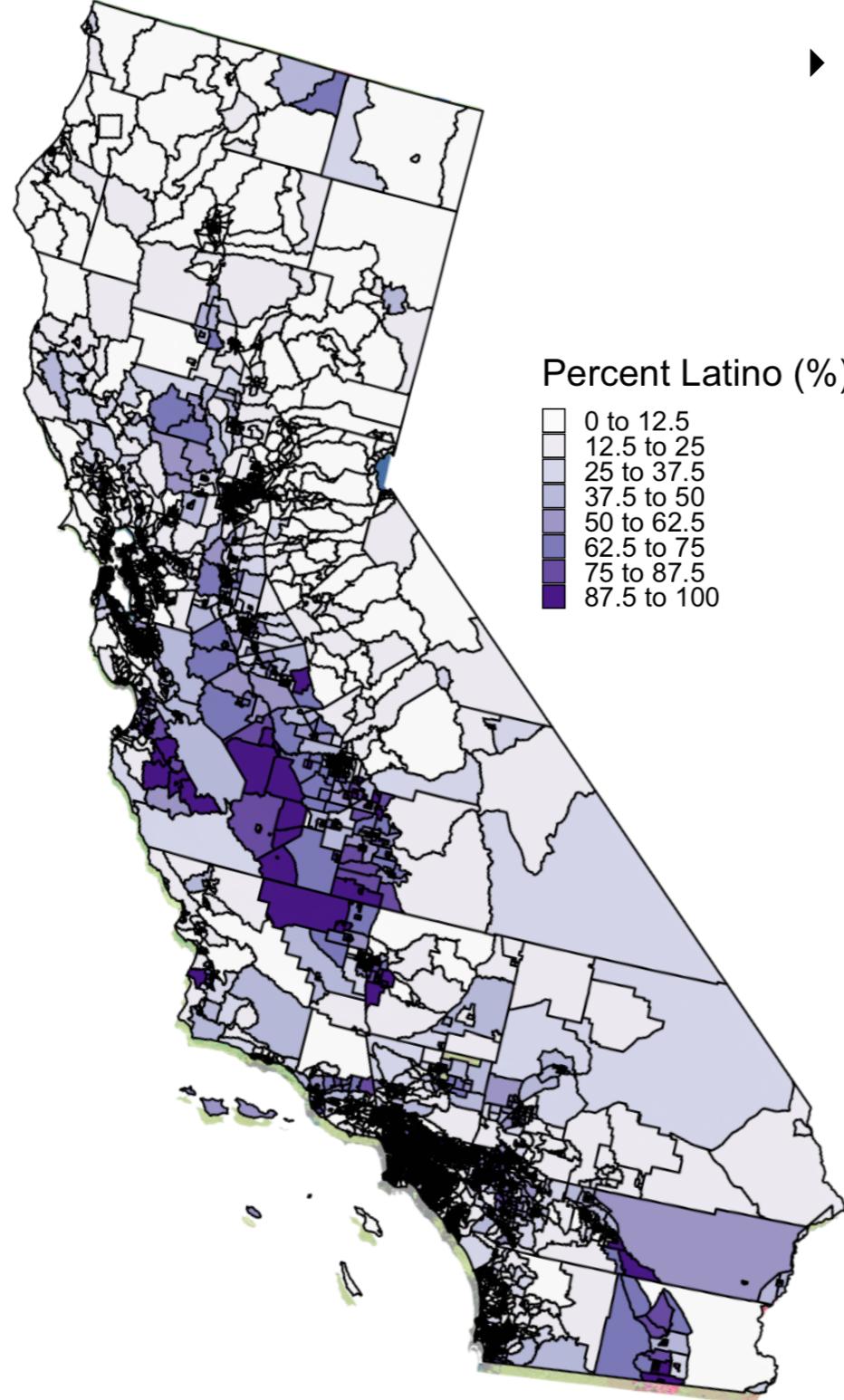
- ▶ Who lives in places vulnerable to drought effects?

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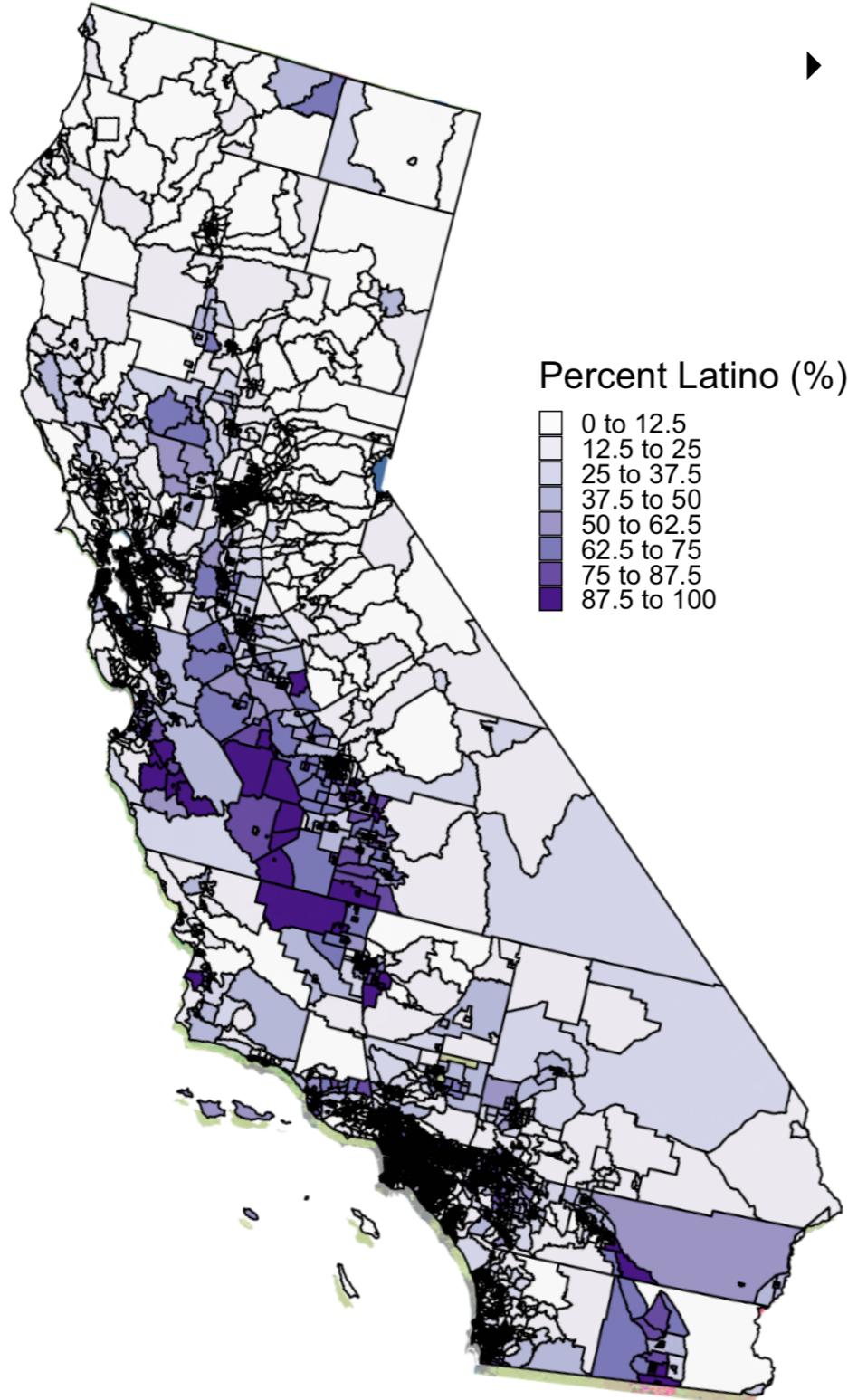
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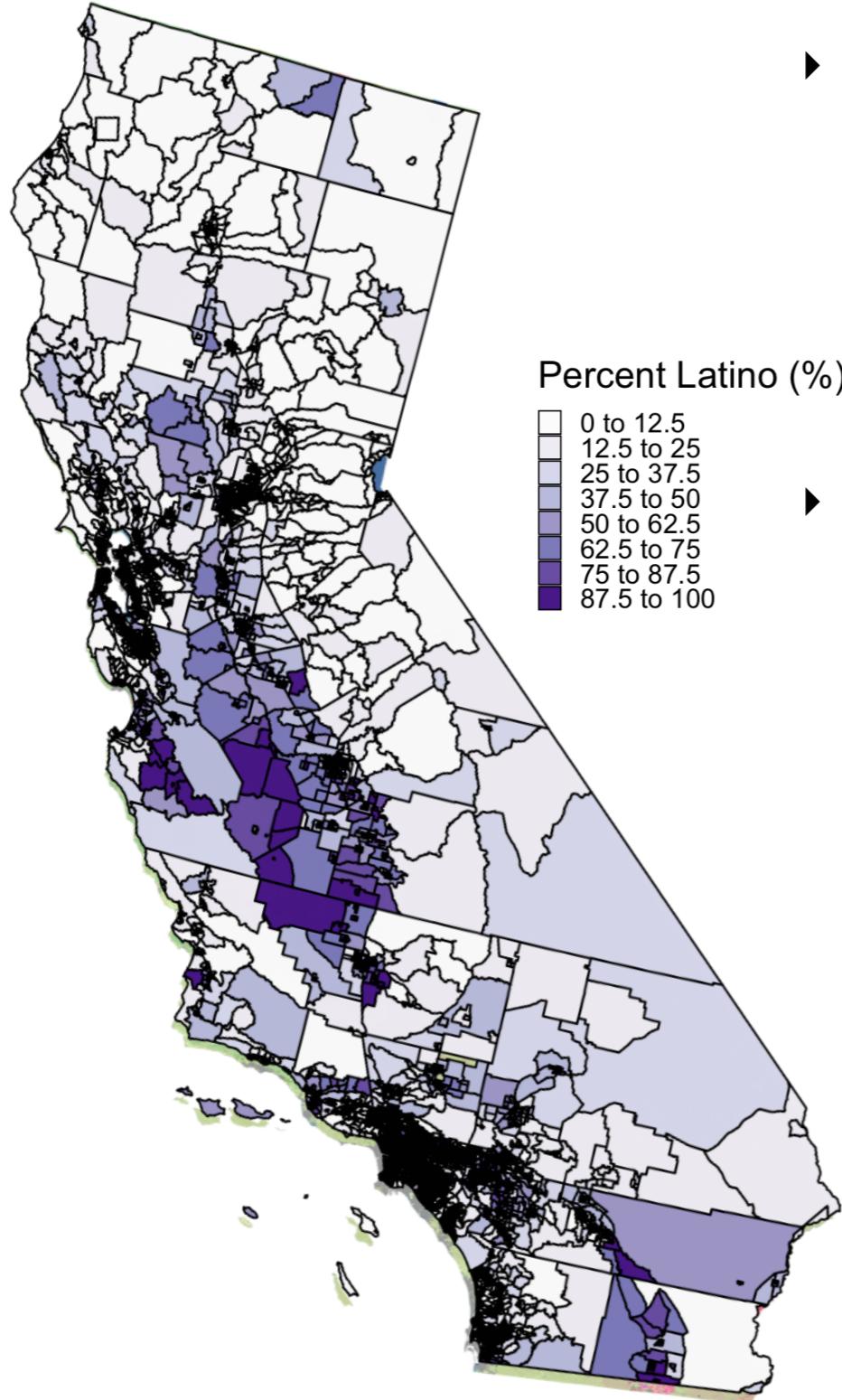
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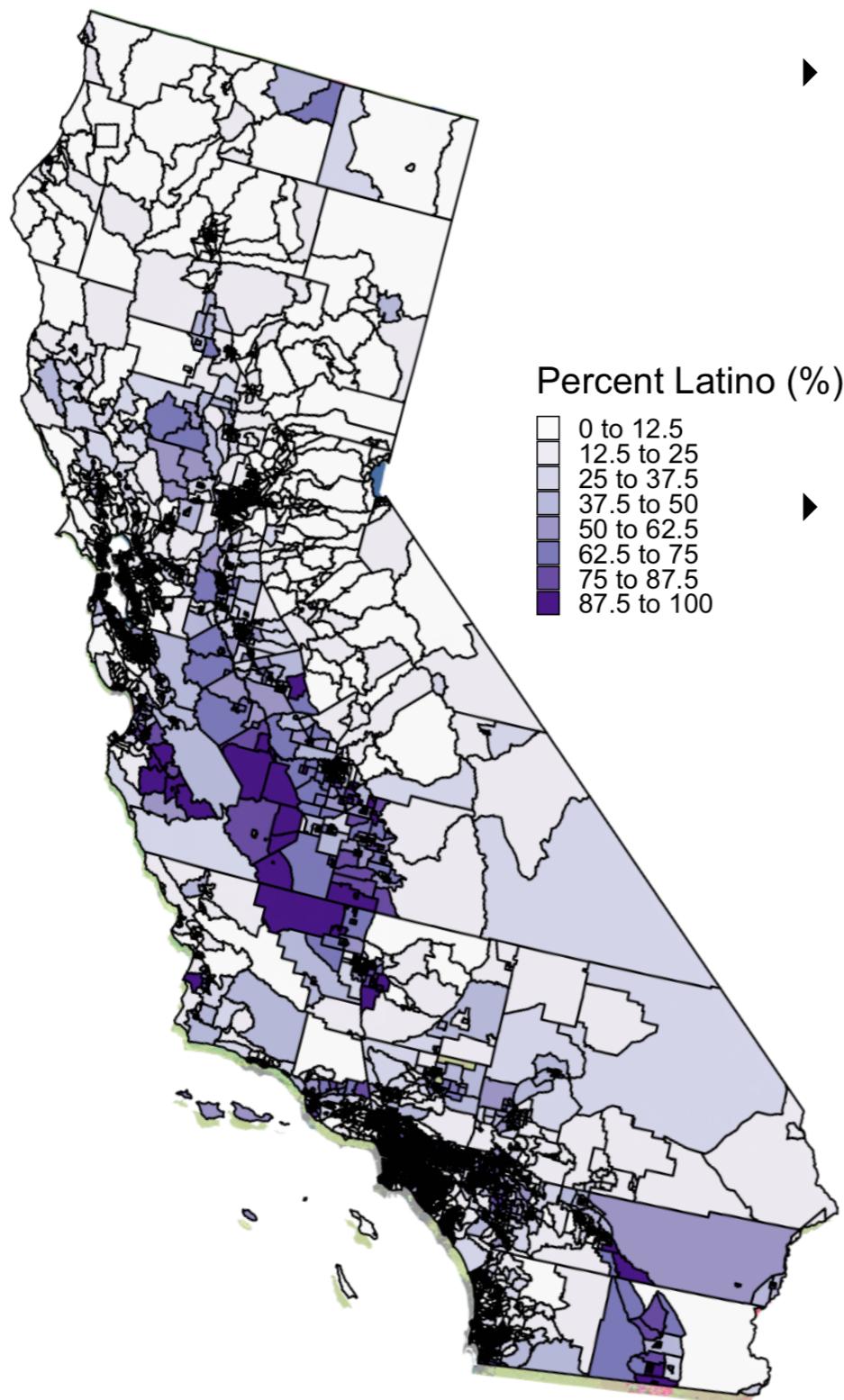
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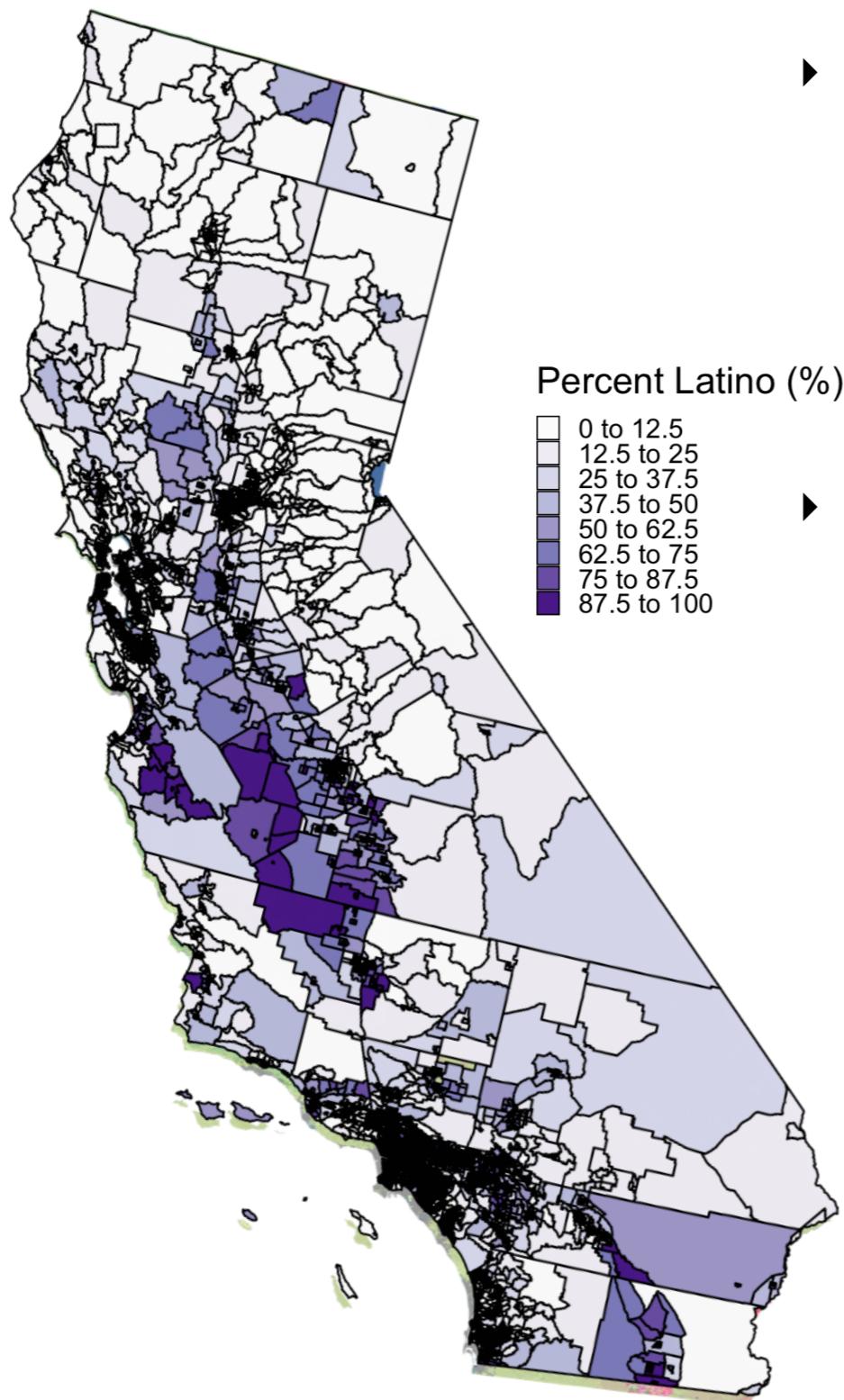
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  - ▶ Agricultural groundwater pumping (in the absence of well-defined property rights) not only imposes costs on others by driving down the stock of water but also by **worsening water quality**

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  - ▶ Impacted communities incur adaptation or health costs

**What is the impact of drought on drinking water quality across different socioeconomic subgroups?**

# Related literature

- ▶ **Drought and water quality**

Smith et al. (2018); Lombard et al. (2021); Levy et al. (2021)

- ▶ **Water quality and environmental justice**

Allaire (2019); Balazs et al (2012); Balazs et al. (2011); Fedinick et al (2019); Nigra et al (2020); Pace el al. (2021)

- ▶ **Qualitative evidence**

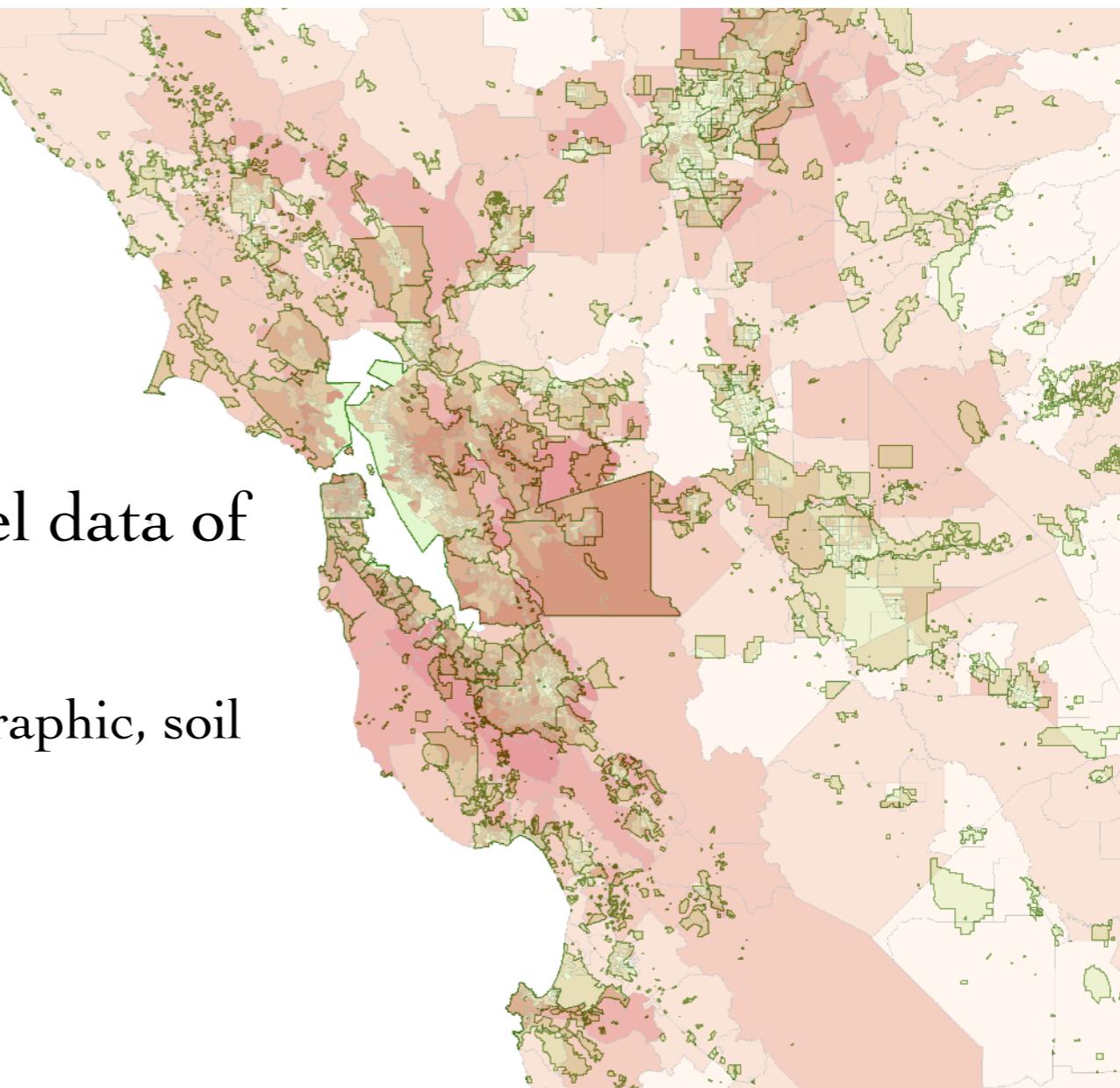
e.g. New York Times (2011, 2012, 2019); The Washington Post (2019)

- ▶ **Costs of groundwater pumping**

e.g. Naumann (2021); Medellín-Azuara (2022)

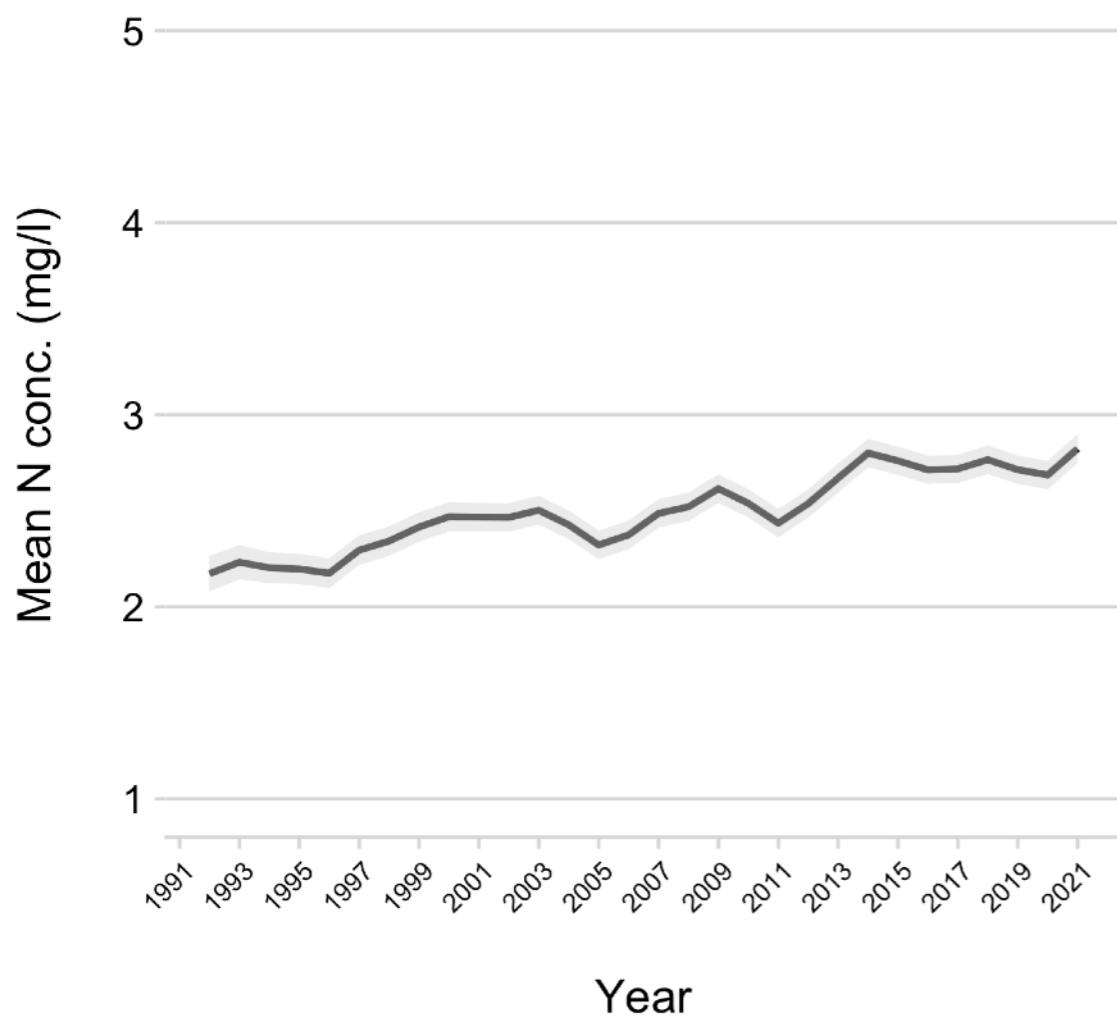
# Data and empirical strategy

- ▶ Regulatory drinking water quality panel data of >3,000 locations across 15 years
  - ▶ + drought, land use, agricultural, sociodemographic, soil characteristics



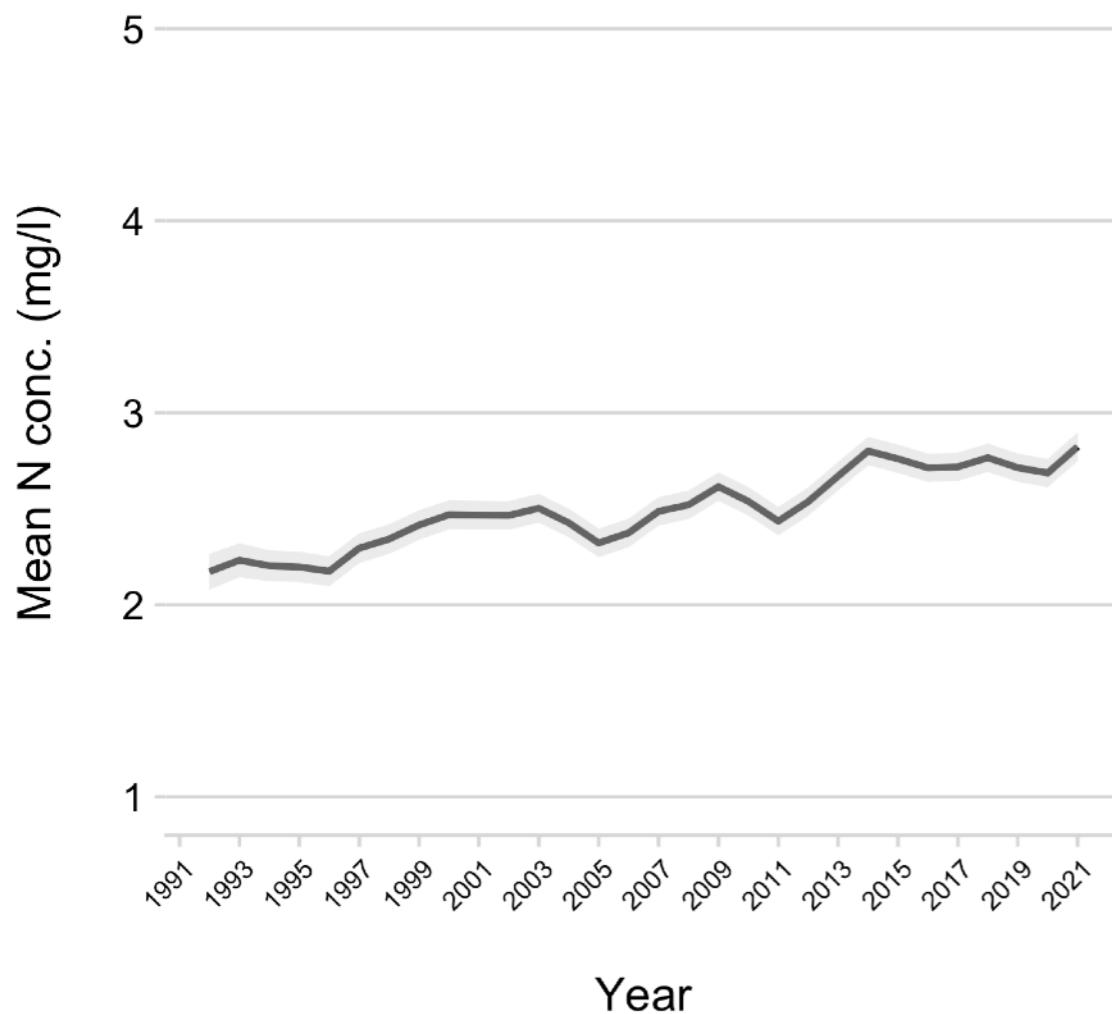
# First glance at the data

## Nitrate in groundwater

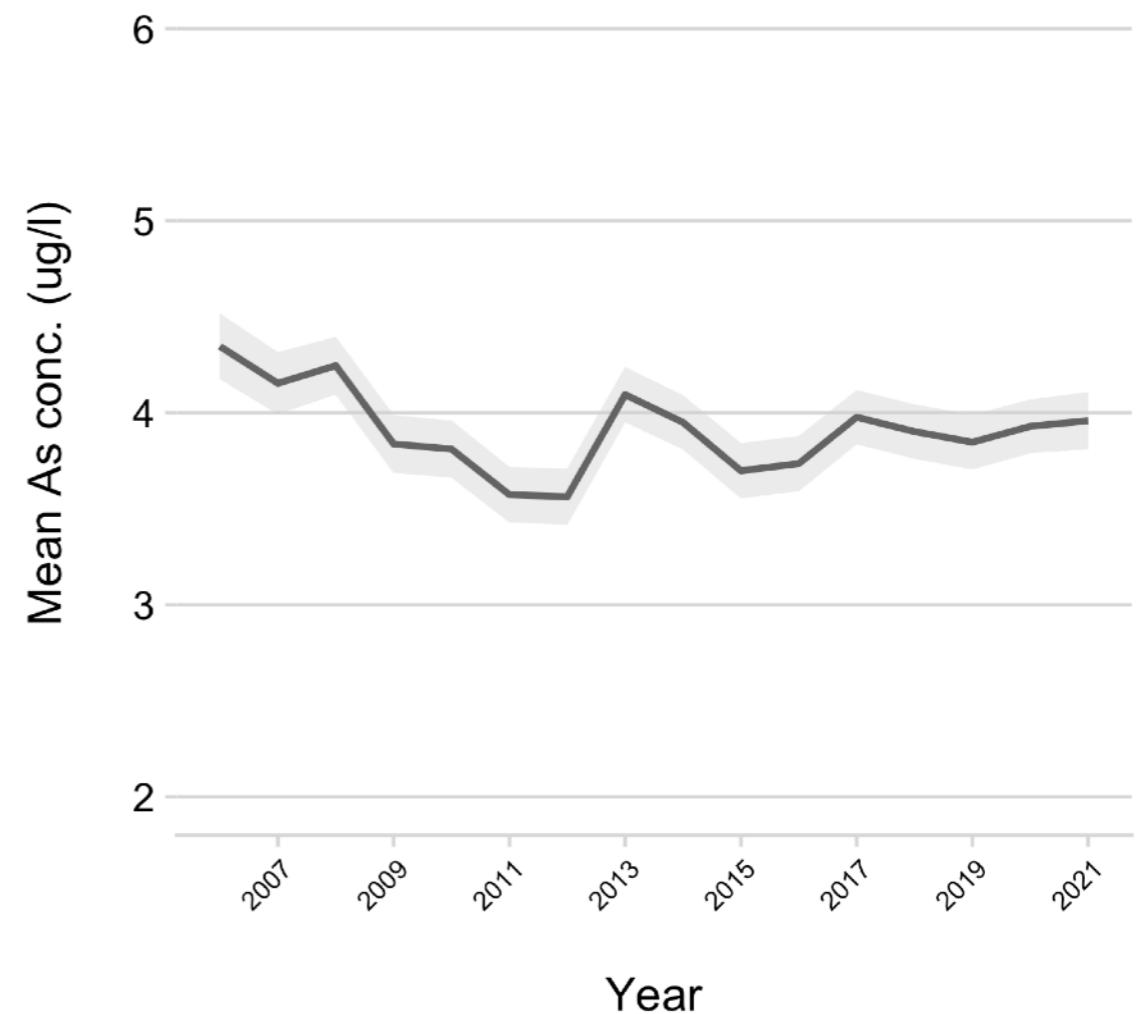


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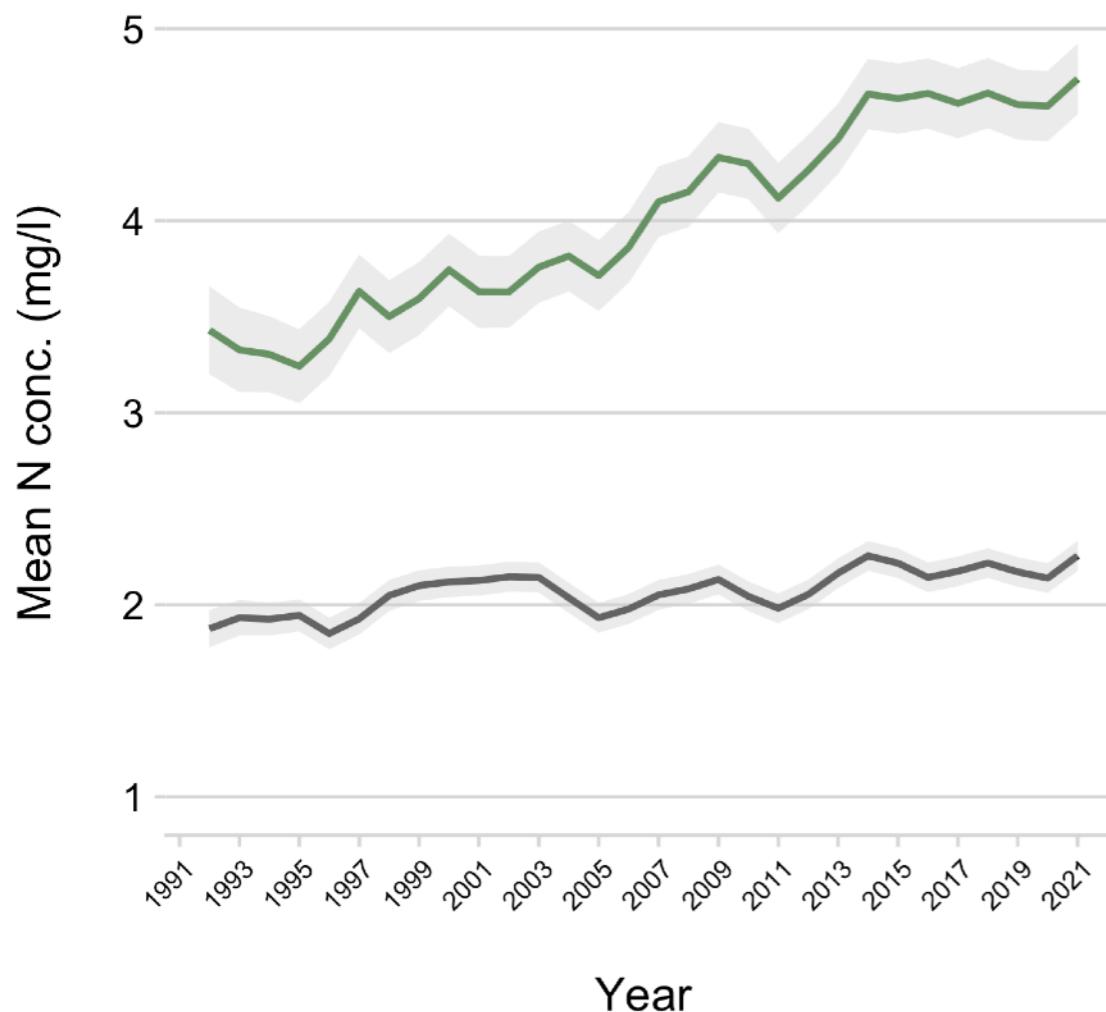
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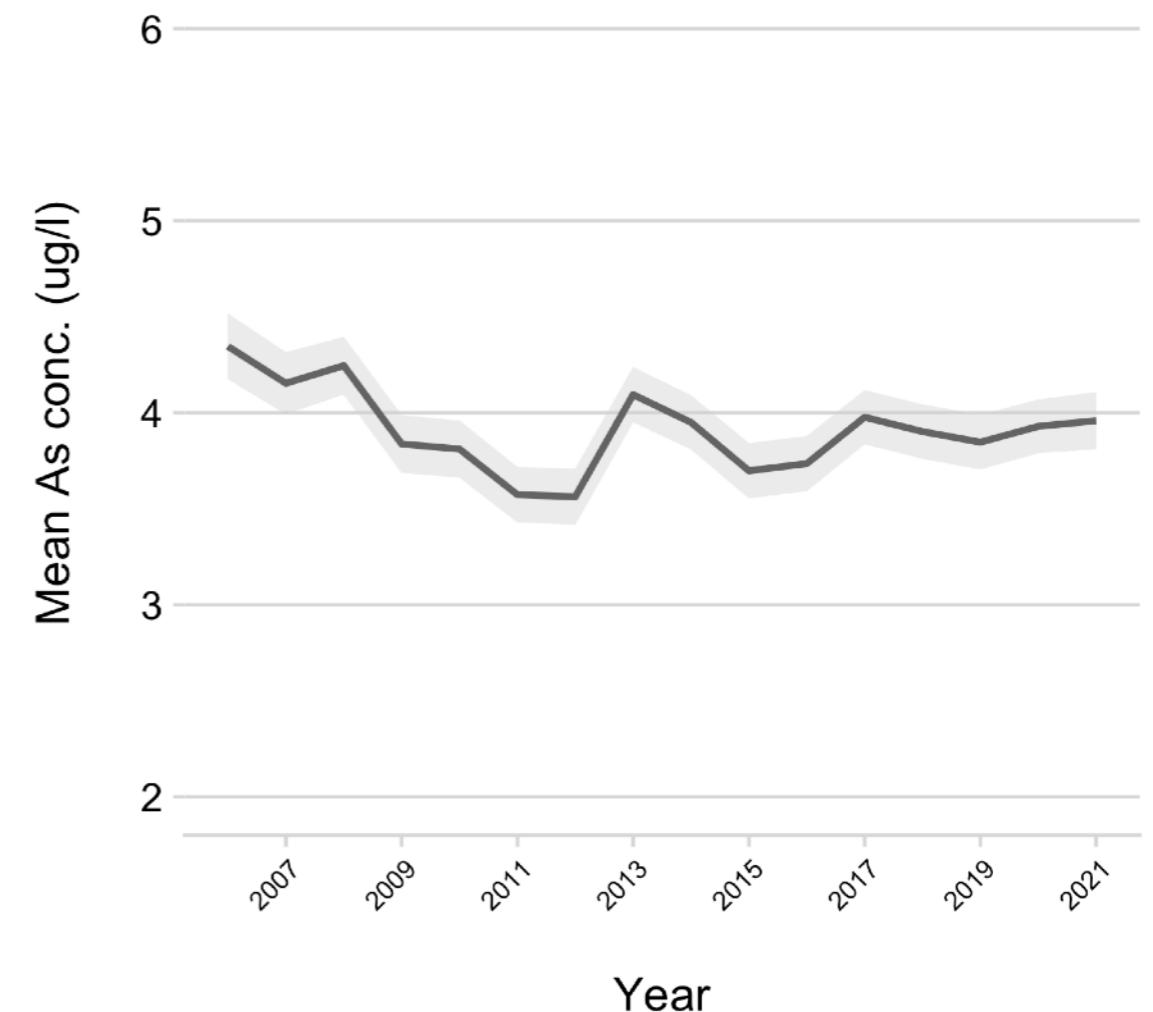
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- All other
- Majority Latino

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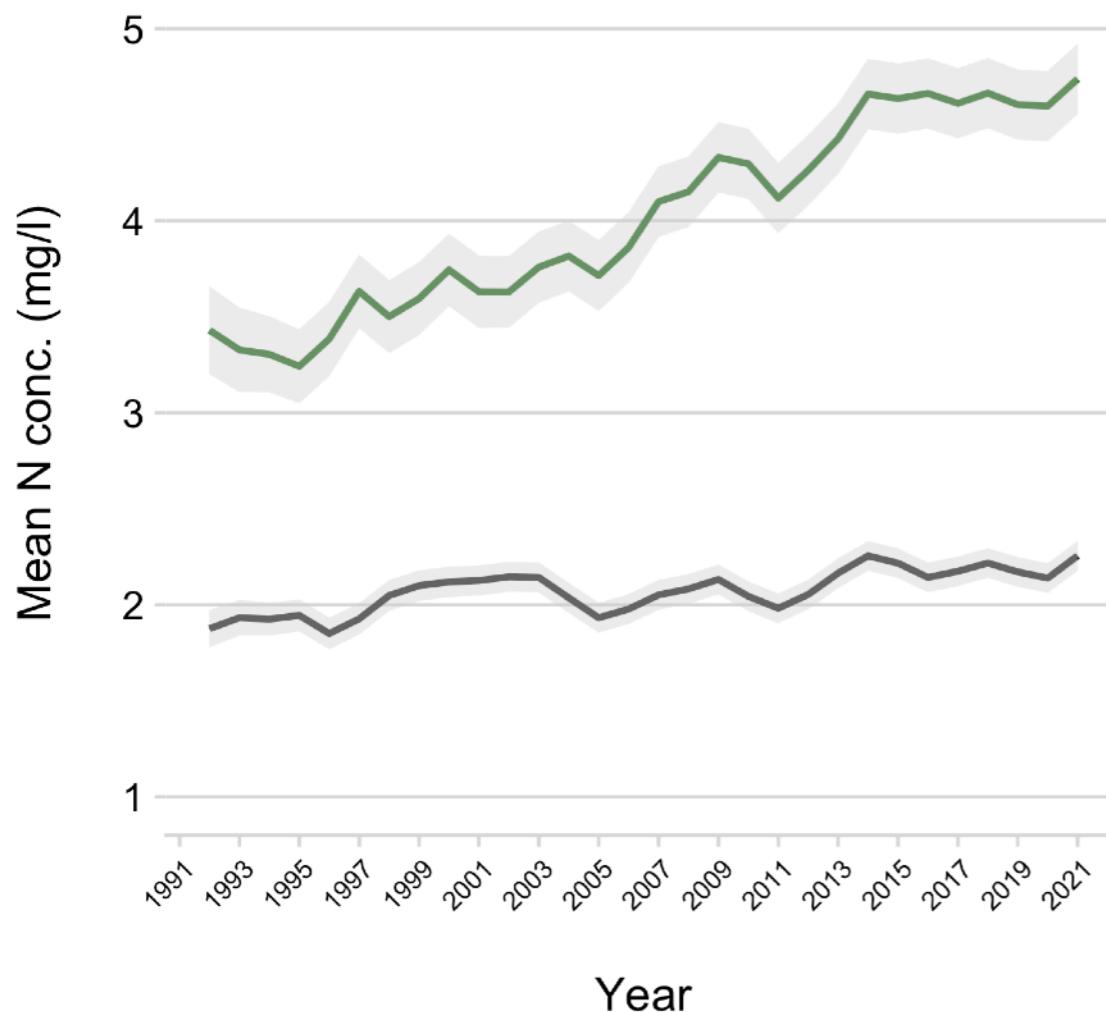
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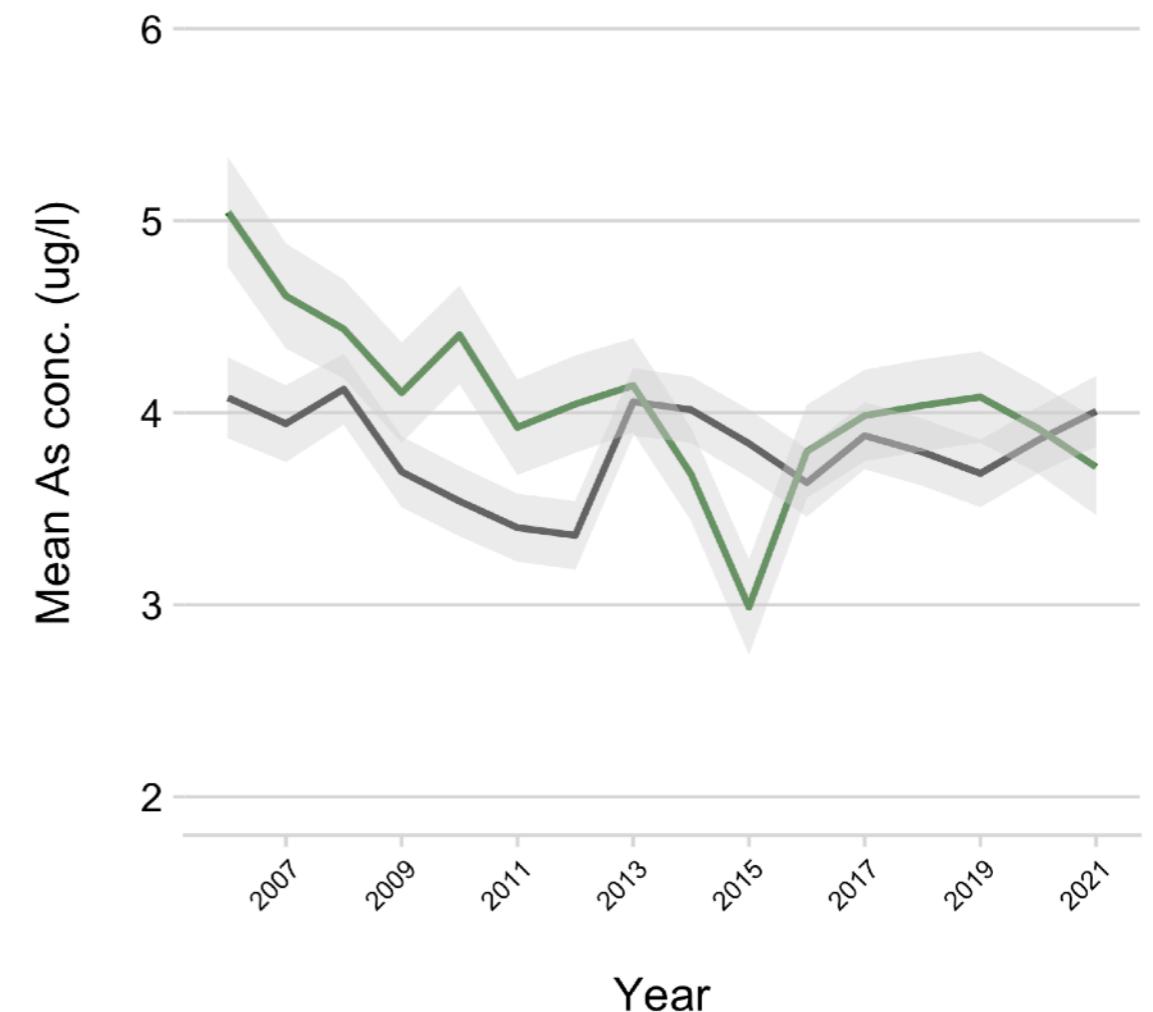
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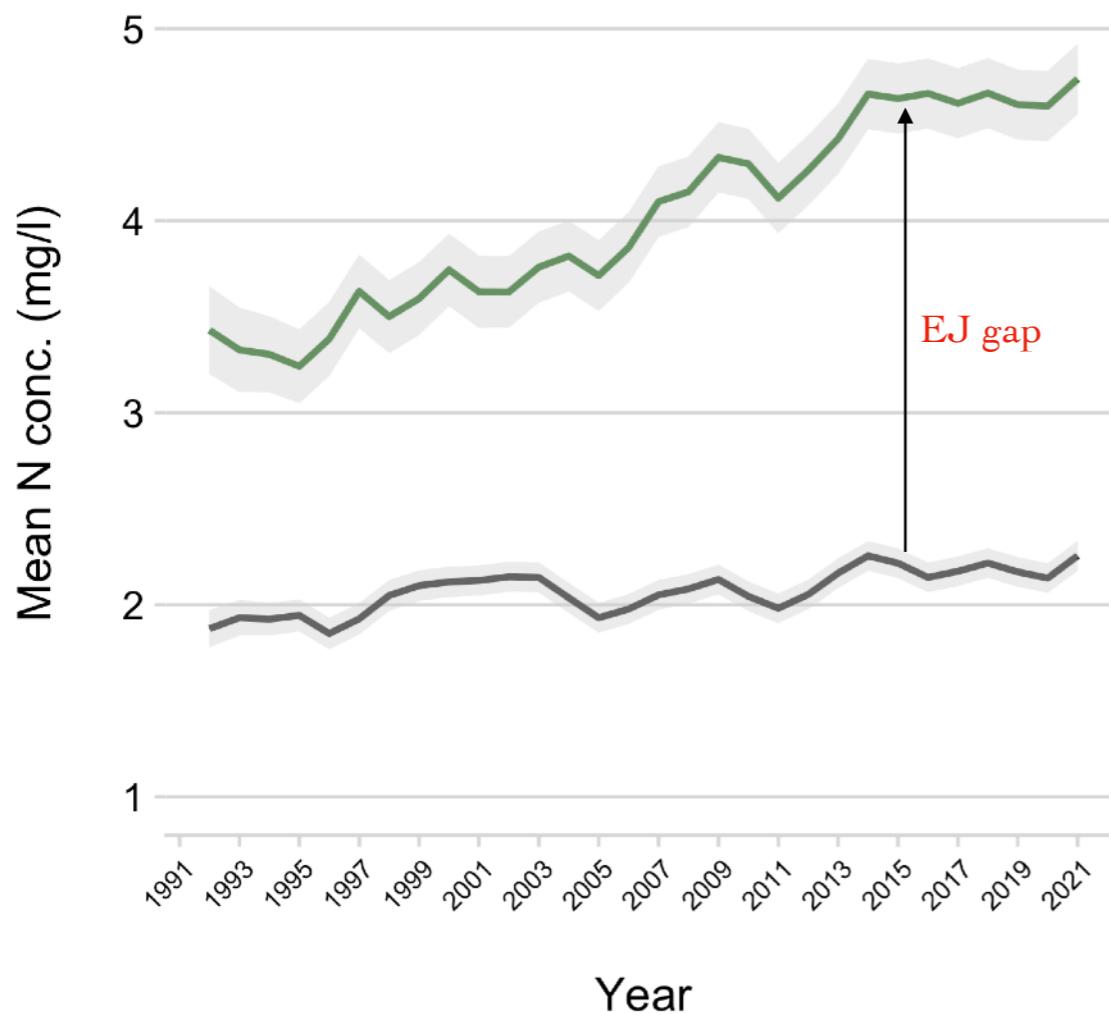
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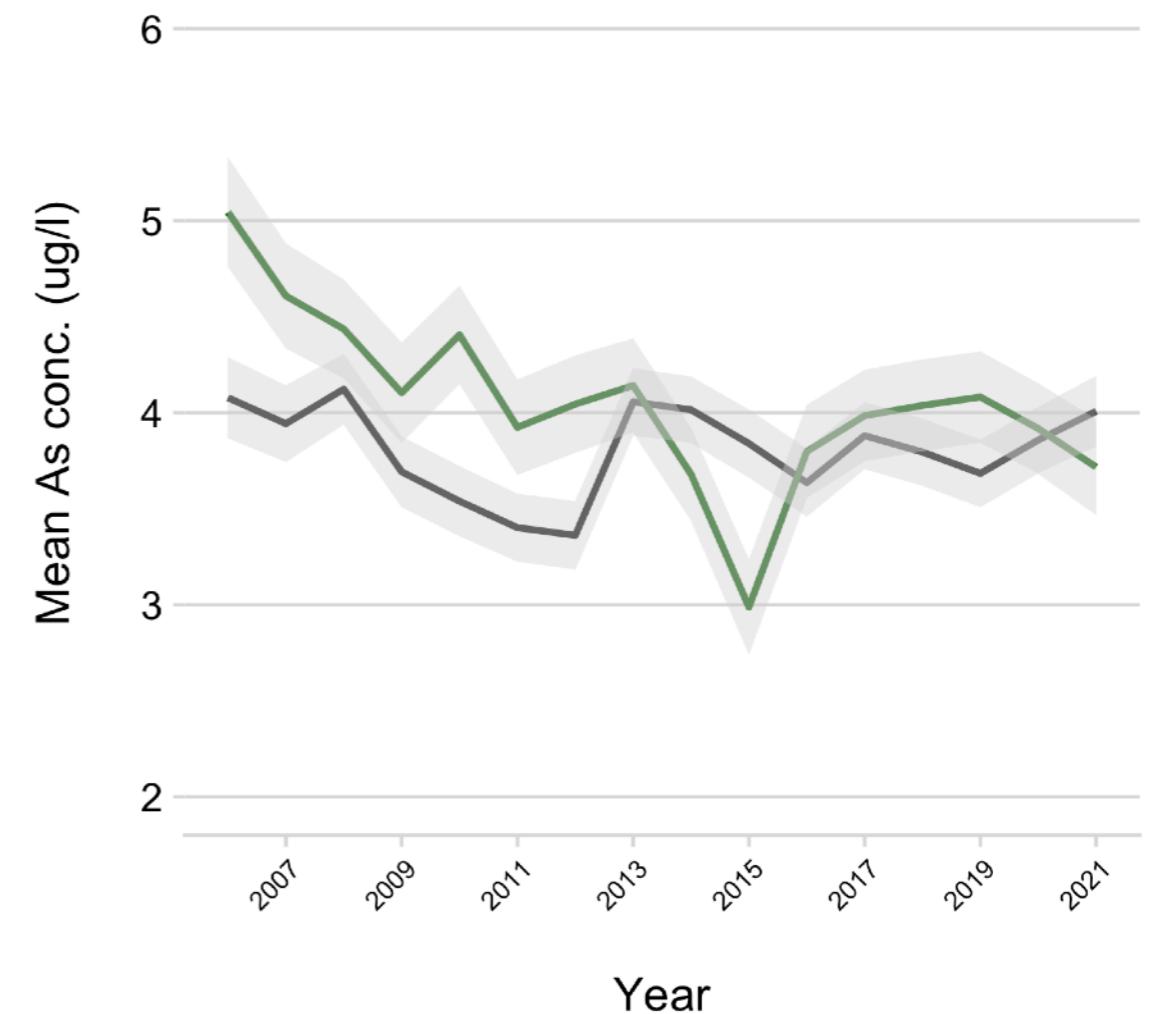
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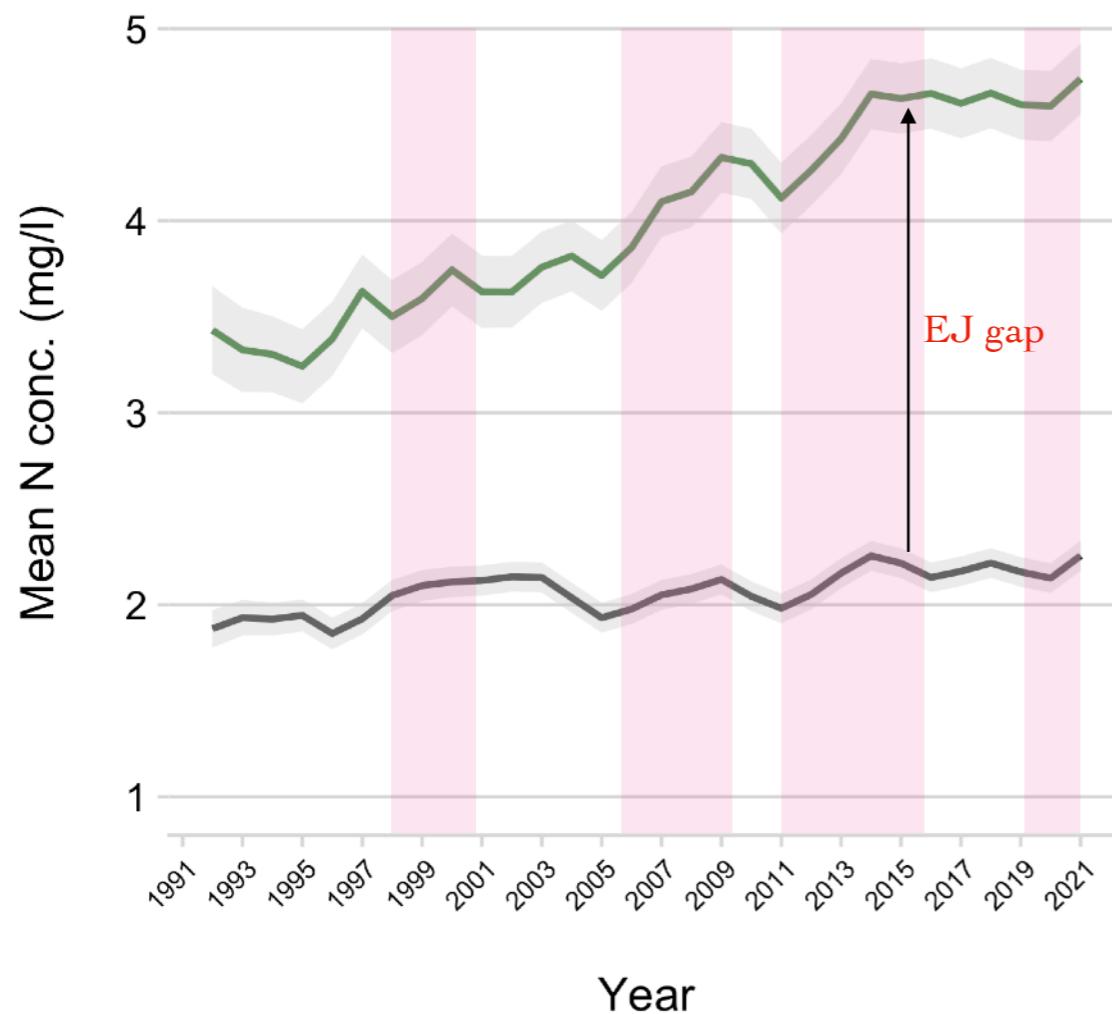


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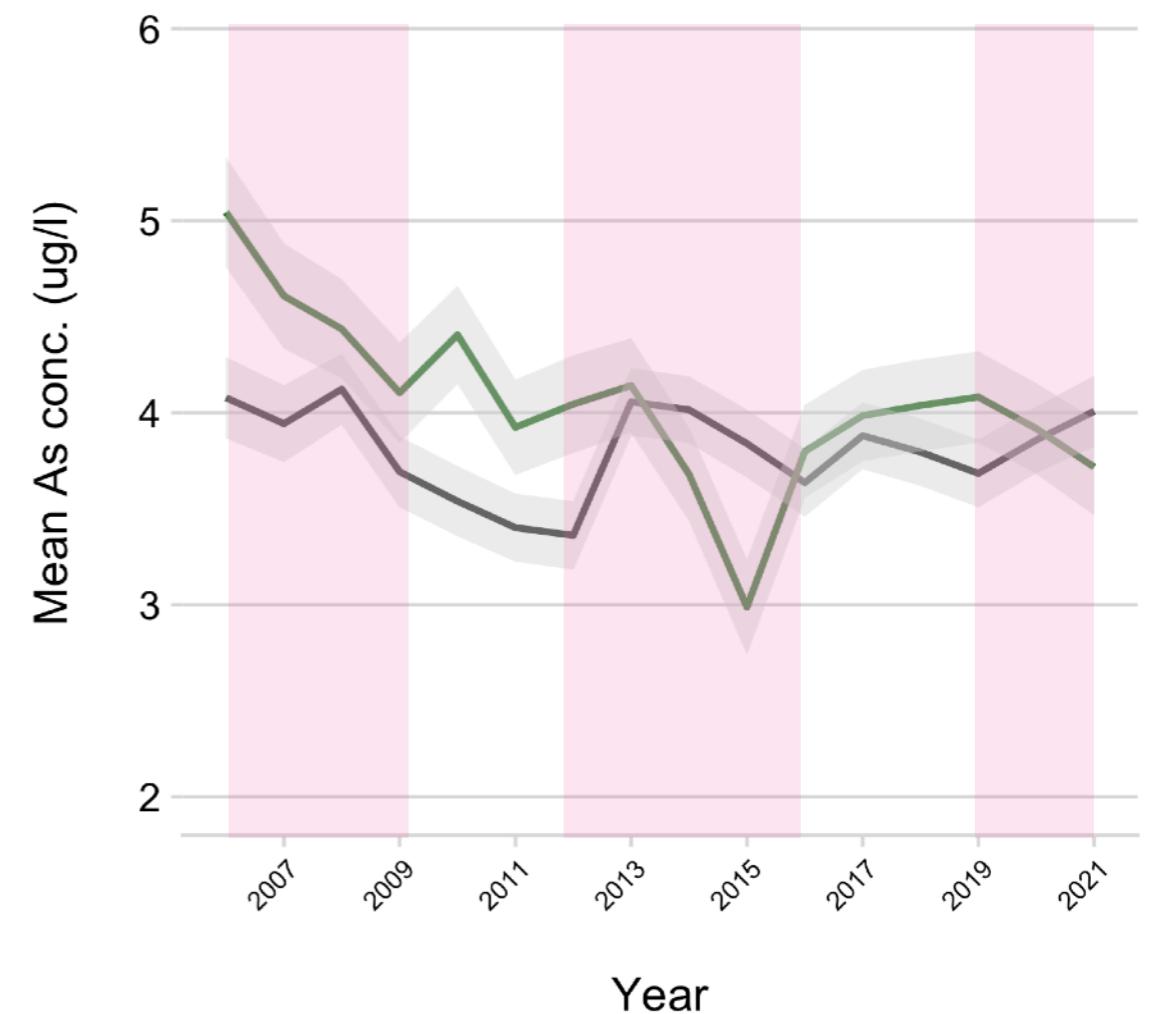
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Drought years

## Nitrate in groundwater



## Arsenic in groundwater



# Empirical strategy

$$C_{iwt} = \beta D_{wt} + \gamma D_{wt} \times \mathbf{1}\{\%Latino > 50\} + \alpha D_{wt} \times \mathbf{1}\{Low\ income\} + \delta_i + \tau_w t$$

**$i$  = sample point**

**$i \in \{G, S\}$**

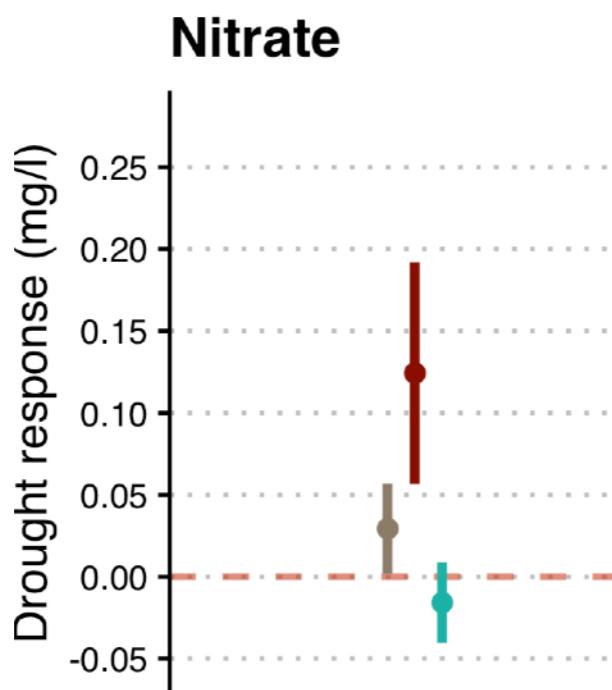
**$w$  = water system**

**$t$  = year**

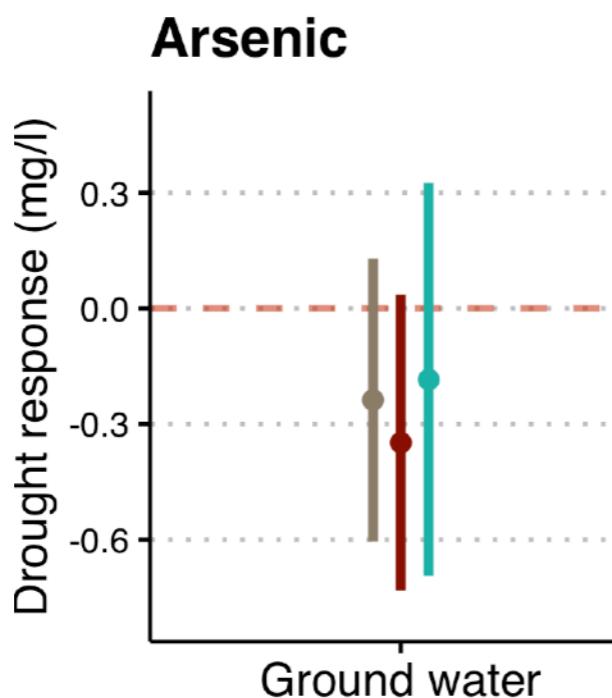
Other baseline econometric specification:

- (i) Tested combinations of geographical, administrative units, and year fixed effects.
- (ii) Interacted drought with measures of agricultural intensity and soil characteristics.
  - # ag wells in 1 mile
  - % crop land in 1 mile

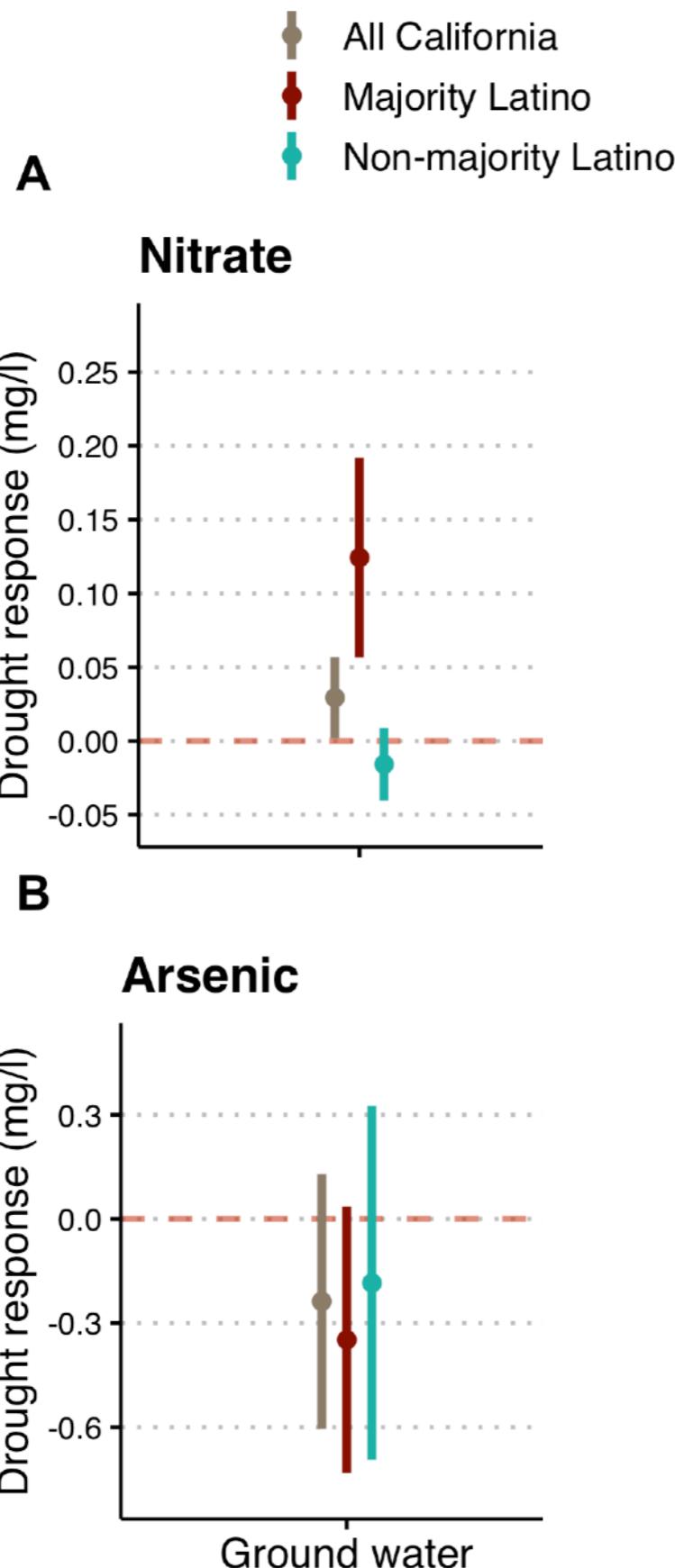
# Results



B

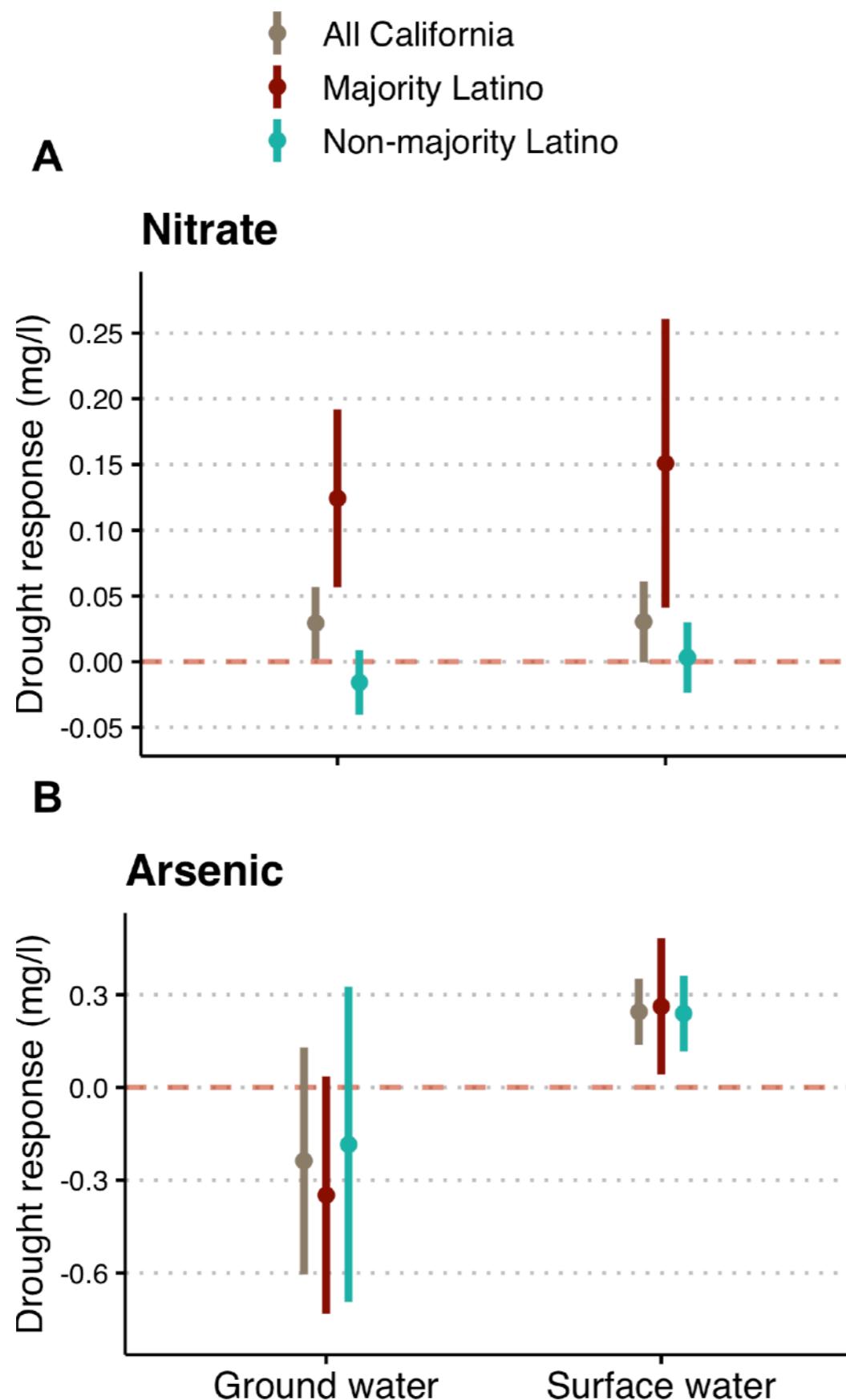


# Results



- ▶ A drought event increases nitrate by **0.13mg/l (5-10%)** **only for Latino communities**
- ▶ + **3.4m** people faced unsafe levels of nitrate because of the 2012-2017 drought
- ▶ No disproportionate effects for arsenic

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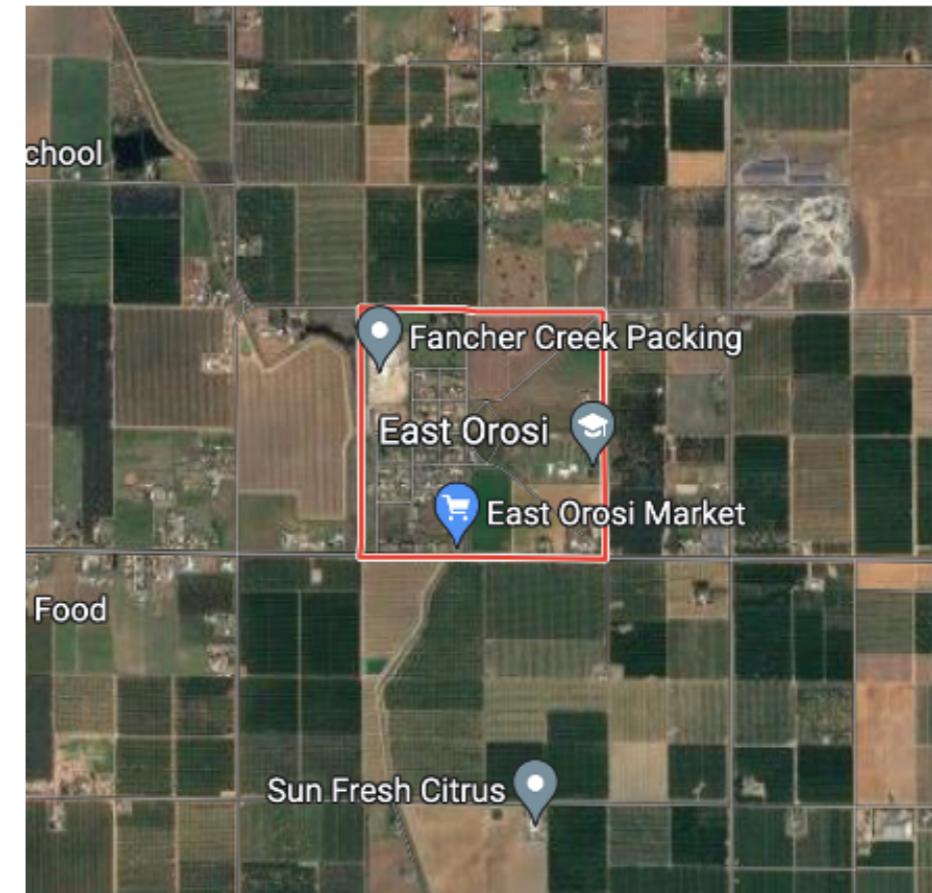
# Cost estimation for 2012-2017 drought

- ▶ Likely incur avoidance or health costs
- ▶ Depends on sociopolitical and behavioral responses

	Invest in new well or treatment	Purchase bottled water	No adaptation
Cost estimate (million \$)	32-160	1,836	Incur health costs
Source	CASWRB drinking water state fund grant projects report 2019	\$30/household from household surveys by Pacific Institute	

**Why isn't income a factor in differential impacts?**

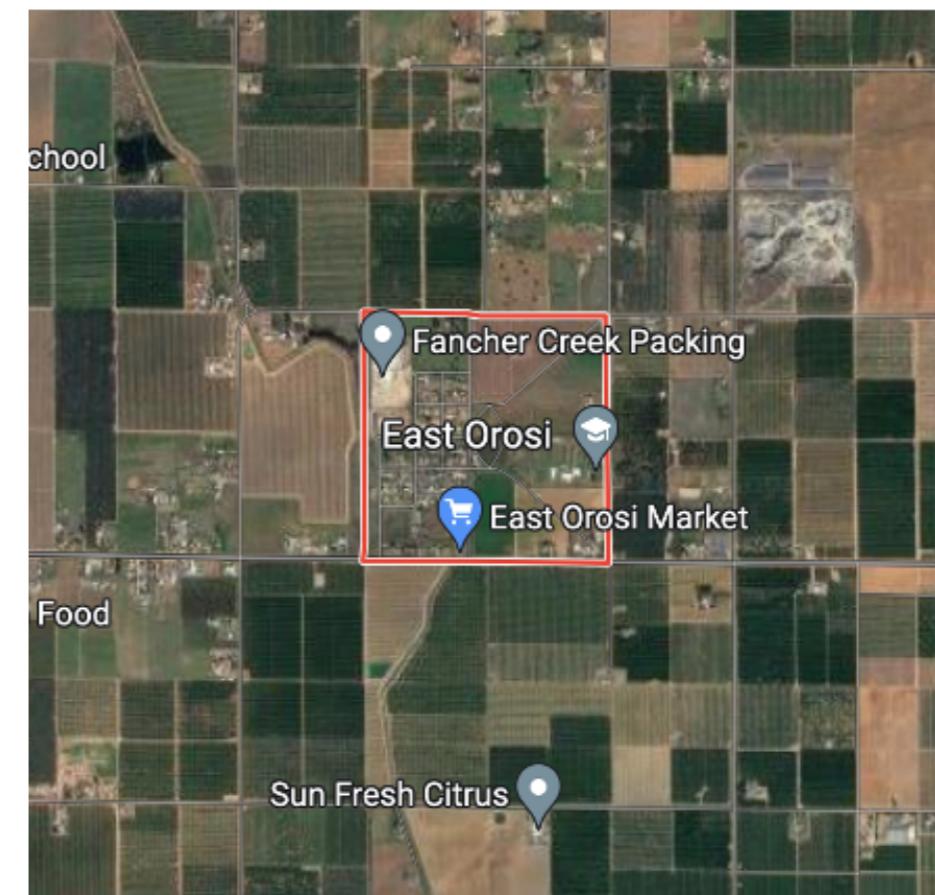
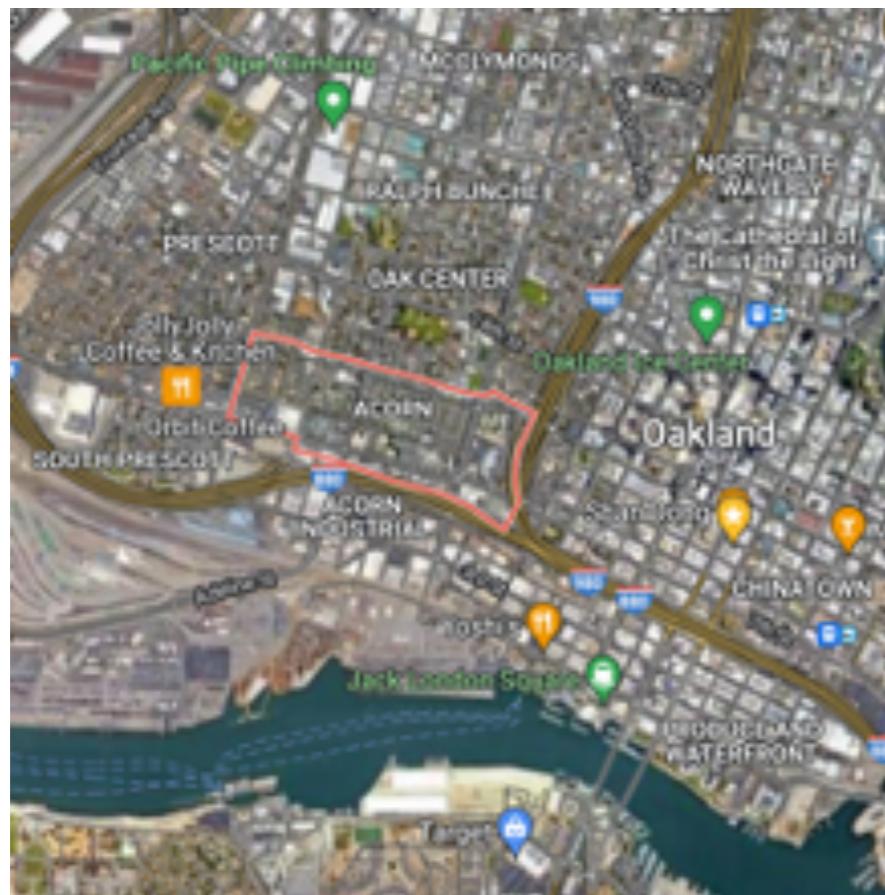
# Why isn't income a factor in differential impacts?



Source: Google Maps, retrieved March 2022.  
Both are neighborhoods with \$30,000 median household income  
but only East Orosi has nitrate problems.

# Why isn't income a factor in differential impacts?

## Can proximity to pumping activities explain the uncovered effects?

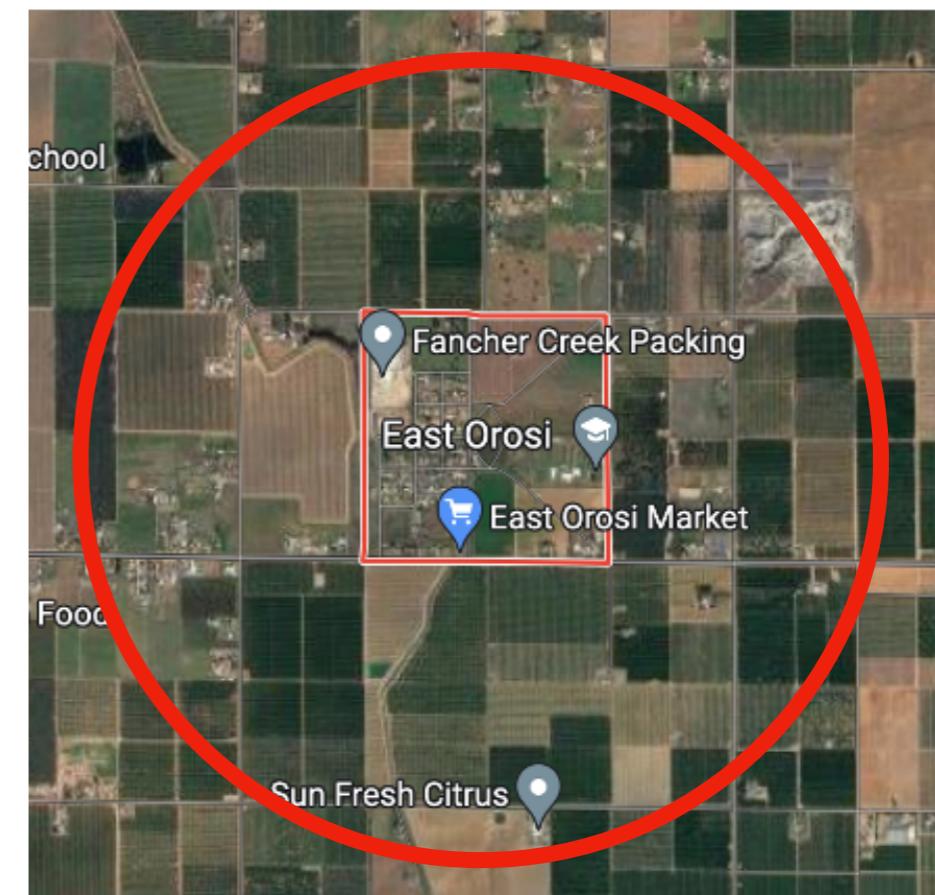


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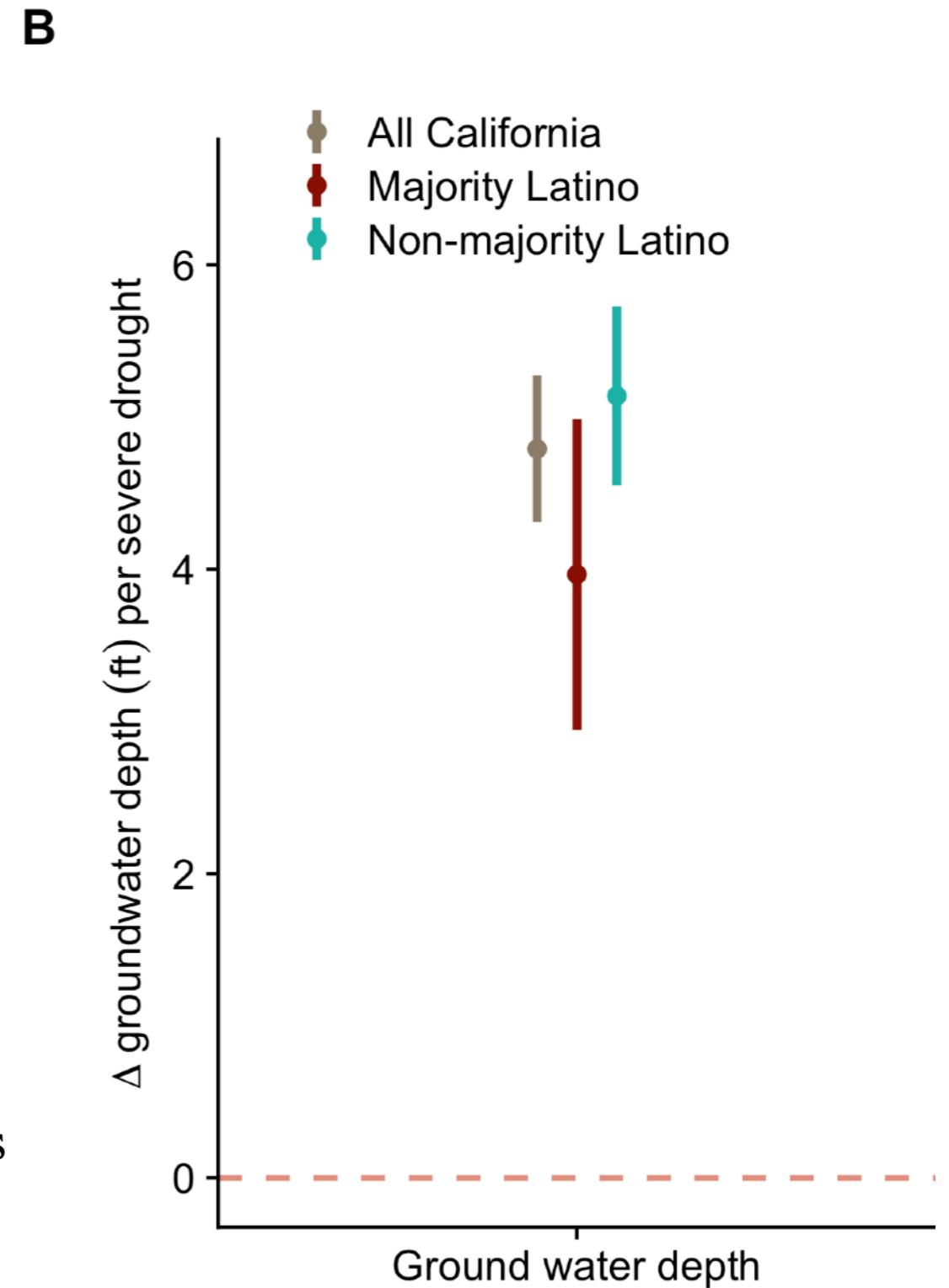
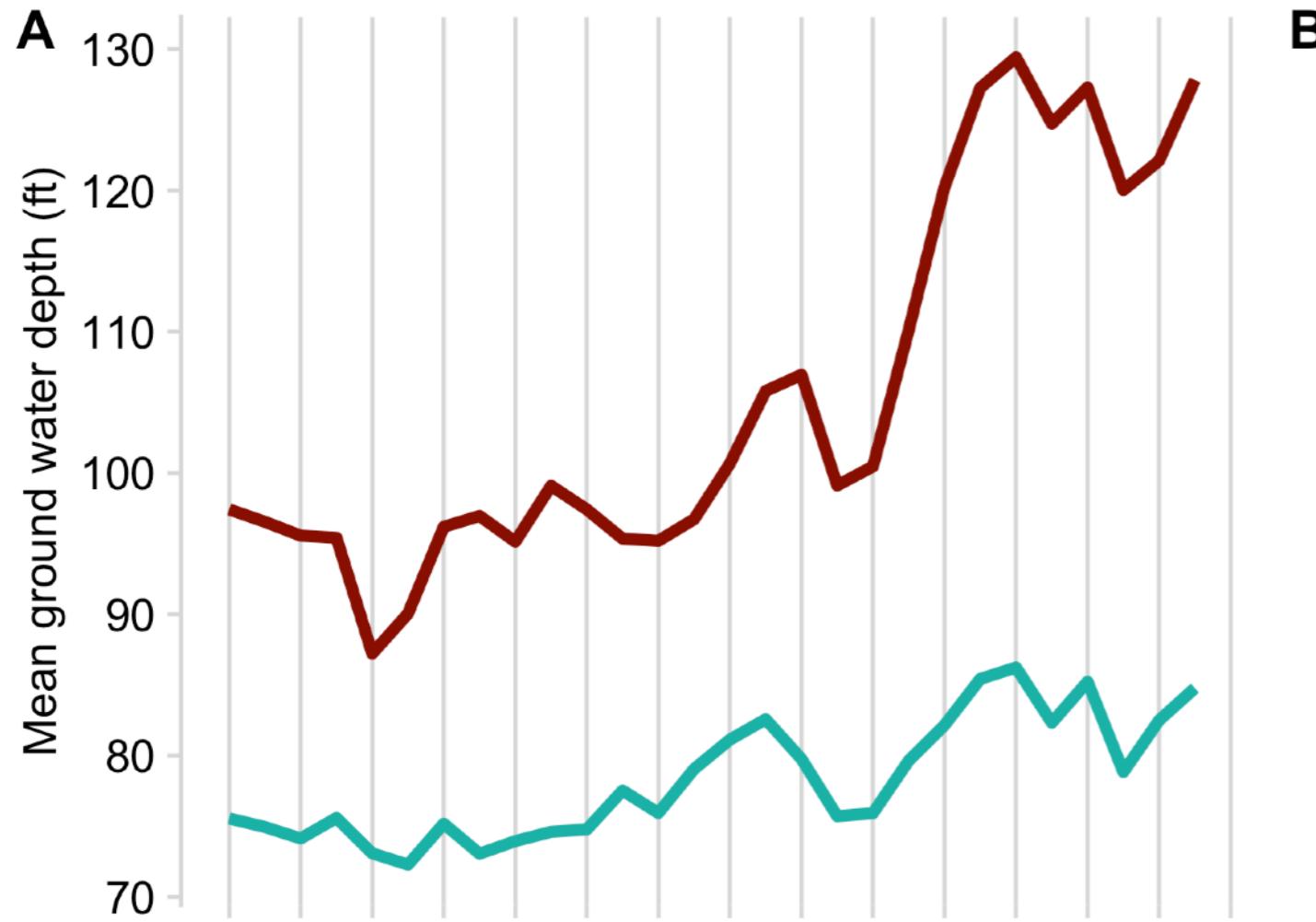
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# Groundwater pumping increases for both group

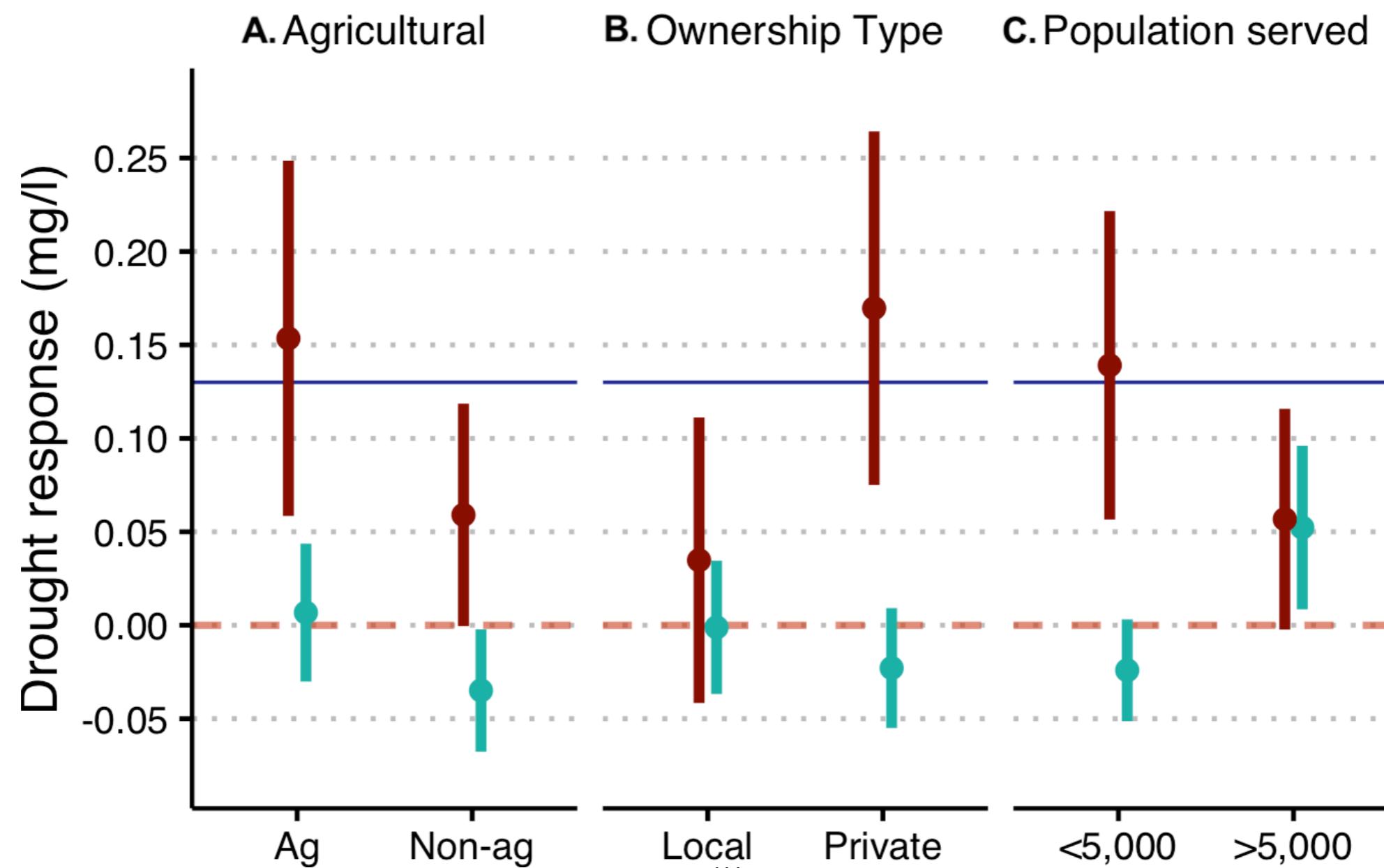


- ▶ Groundwater pumping trends and responses to drought are similar across both groups

# Exploring mechanisms

## Groundwater DWN

Majority Latino      Non-majority Latino

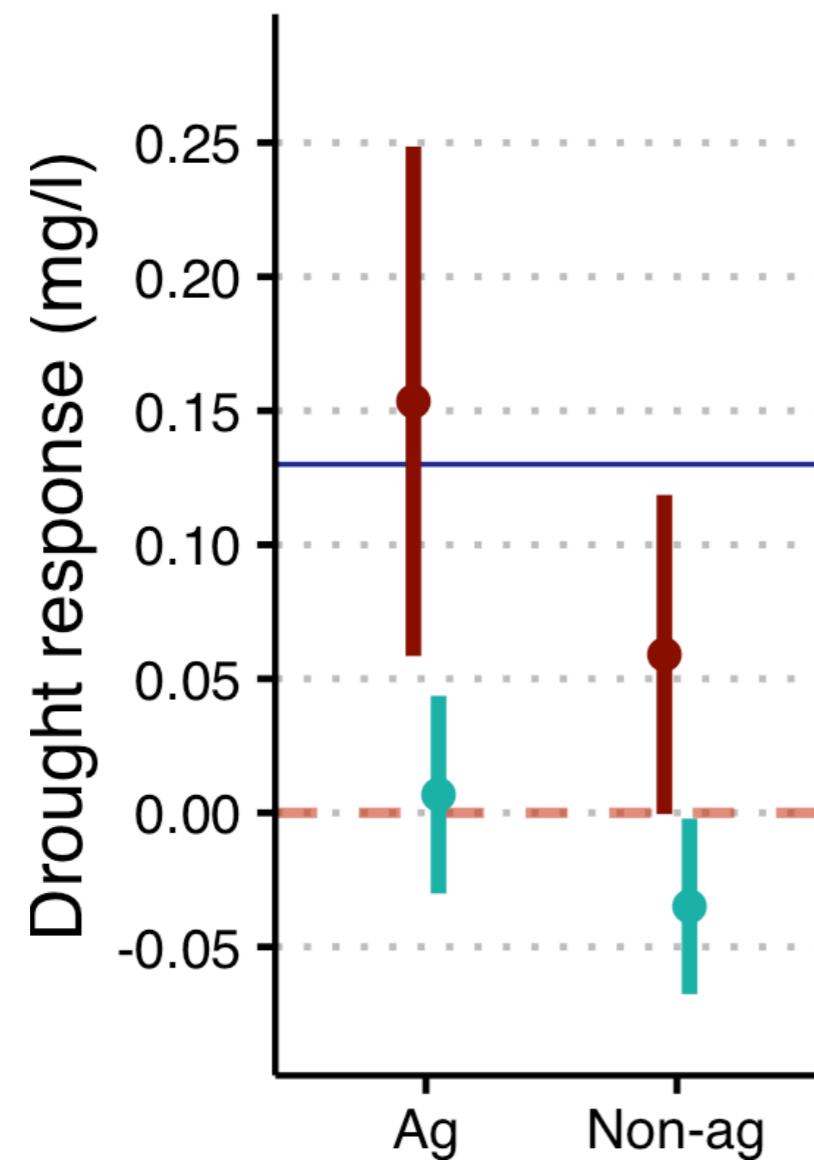


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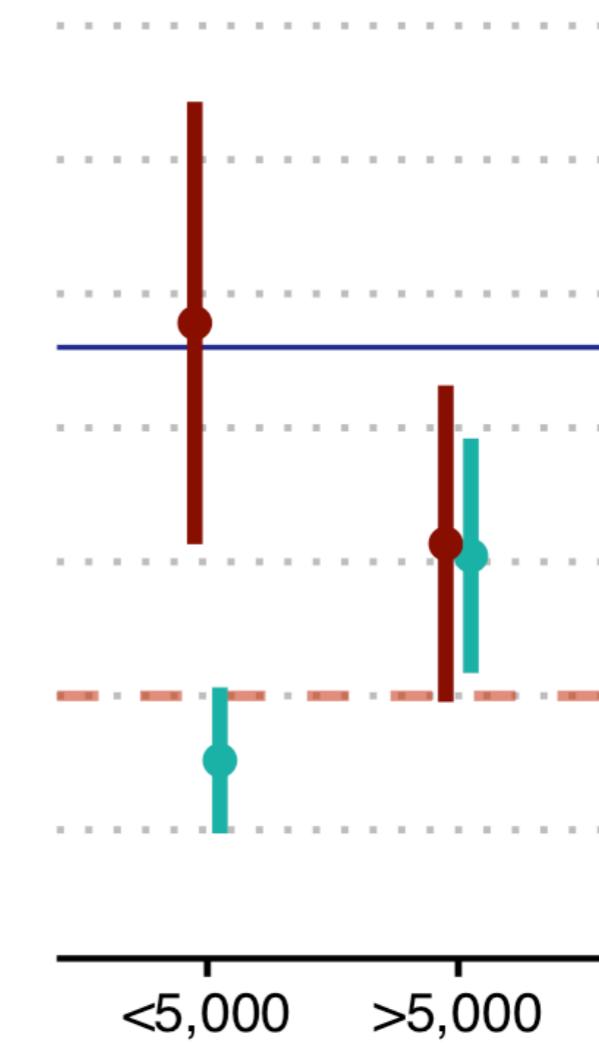
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A. Agricultural



C. Population served

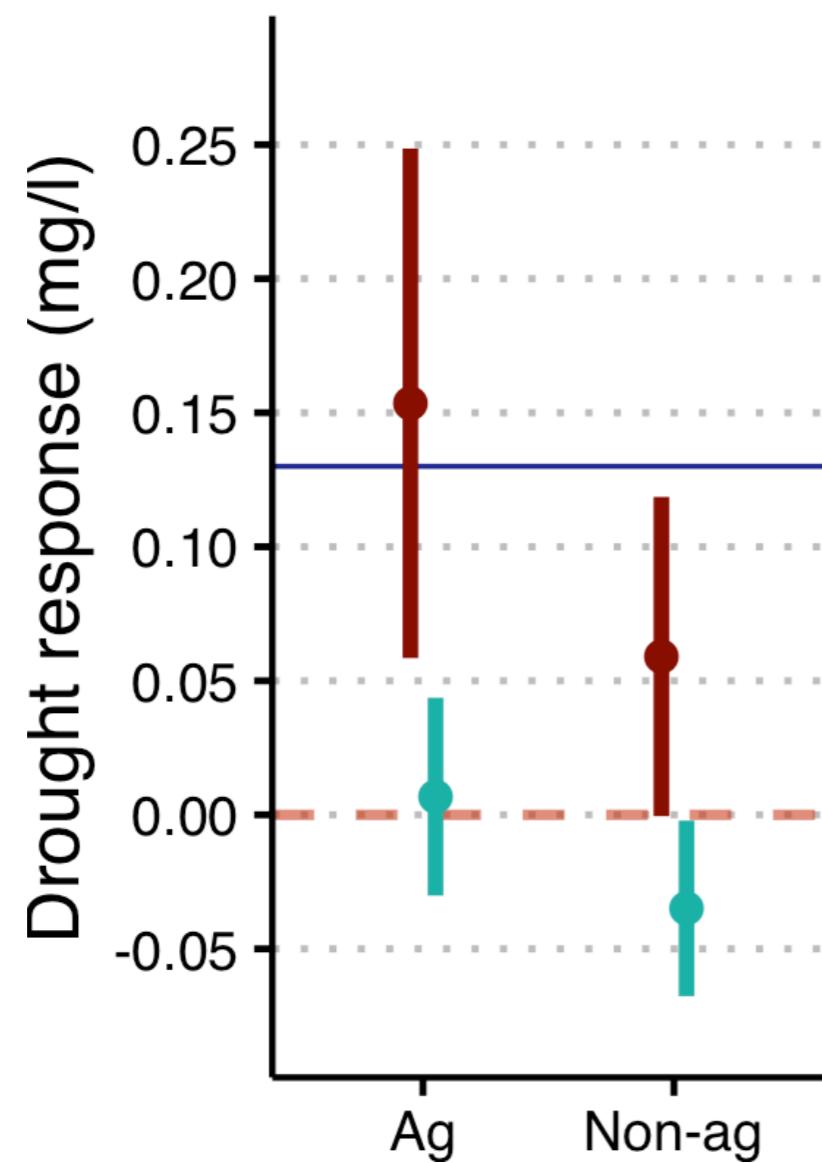


# Exploring mechanisms

## Groundwater DWN

Majority Latino      Non-majority Latino

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# Unpacking the locus of injustice

- ▶ Overt racism
- ▶ Systemic racism
- ▶ Political power
- ▶ Land markets, “sorting”
- ▶ Private vs public good?

# Conclusion

## Key takeaways

- Large and increasing drinking water disparity
- Drought further widen this “gap”
- Disproportionate effects appear to be driven by numerous **small** and **private** water providers
- How do we design equitable and resilient water systems?
  - April 2023: **\$270m** to New York and **\$391m** to California for water infrastructure upgrades