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

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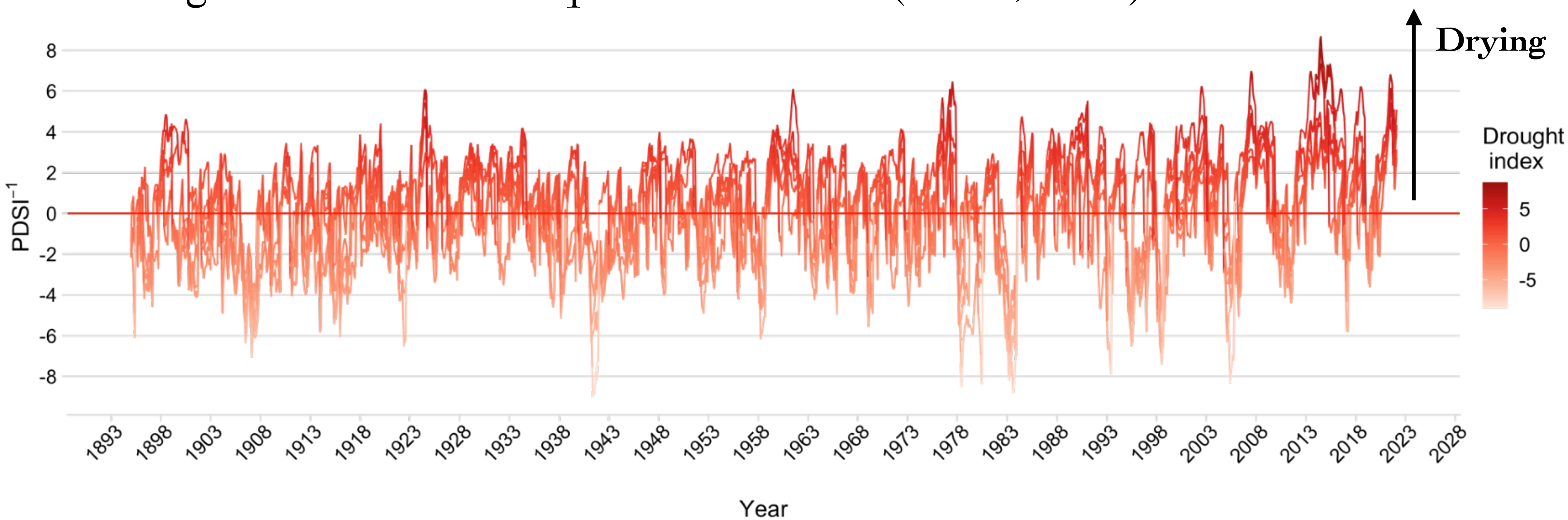
Motivation

- 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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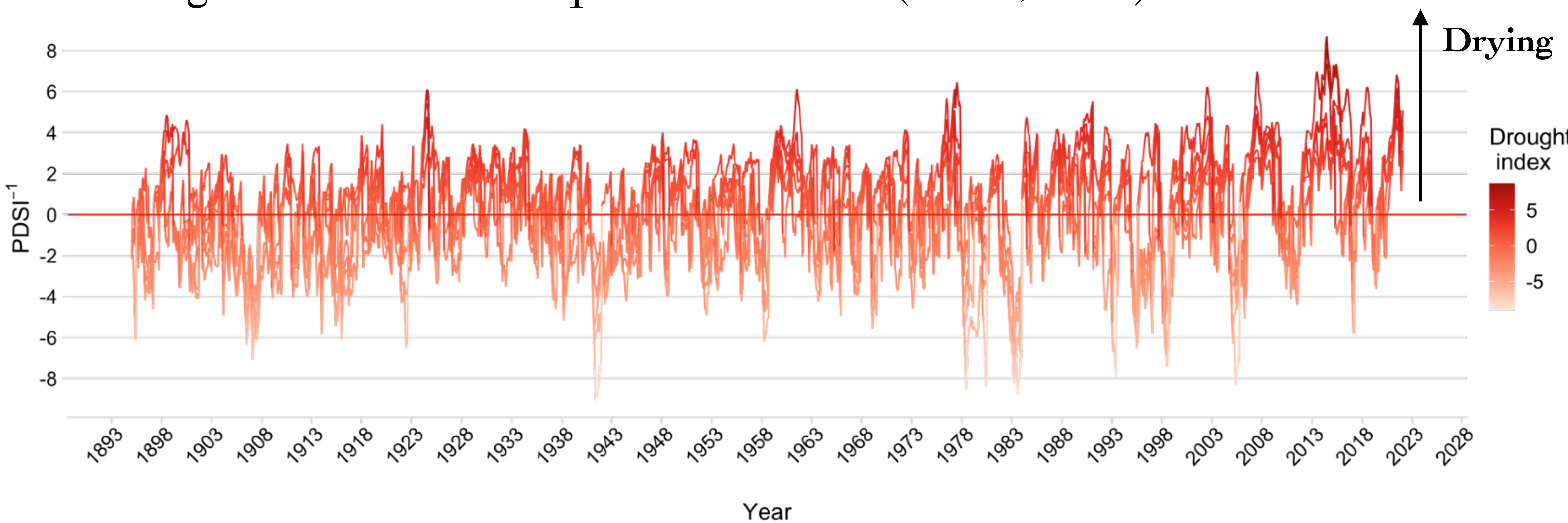

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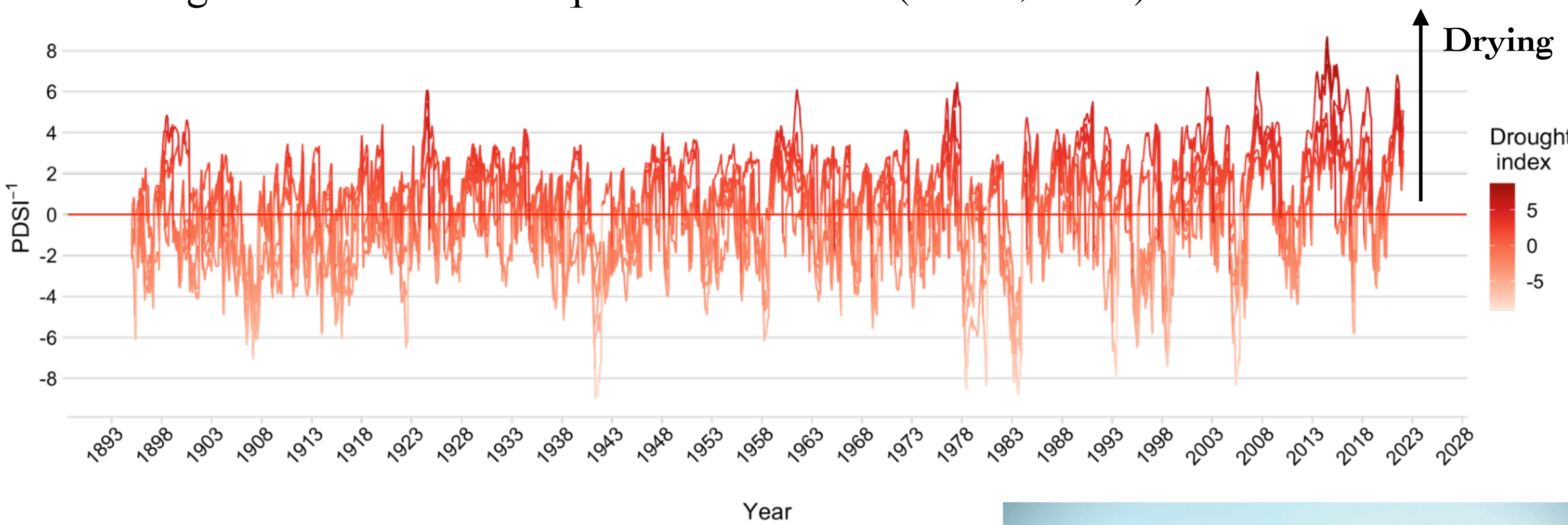

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Credit: Gregory Urquiaga/UC Davis

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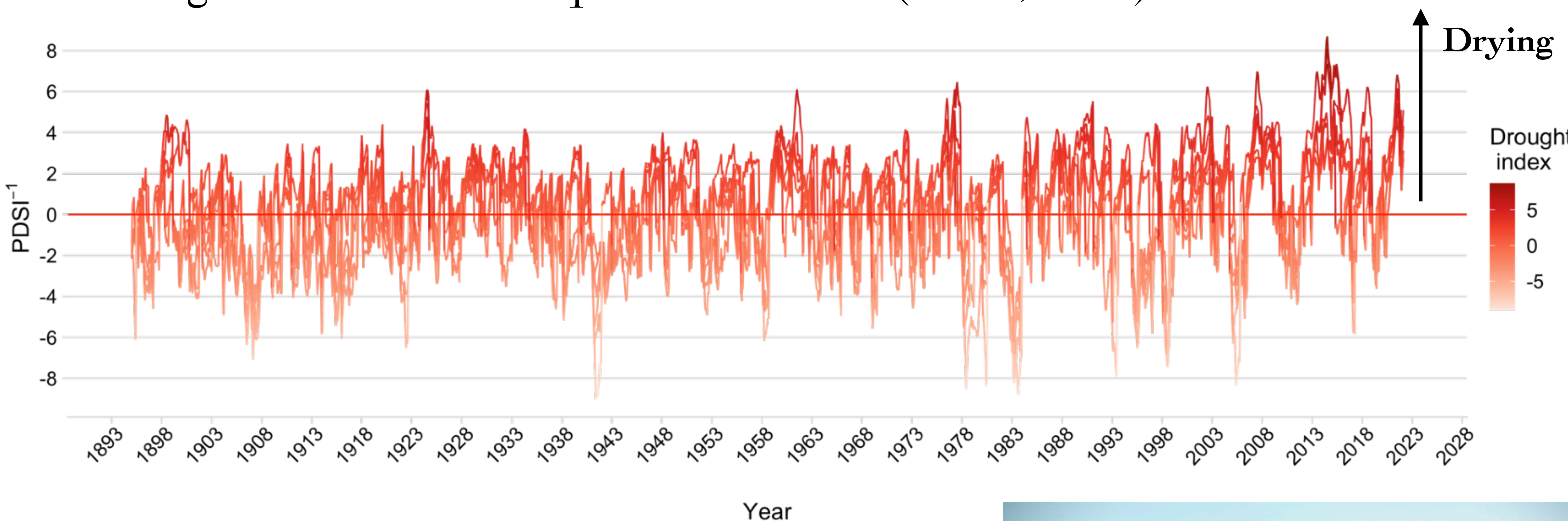

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  - Water shortages → agricultural losses and domestic water supply disruptions

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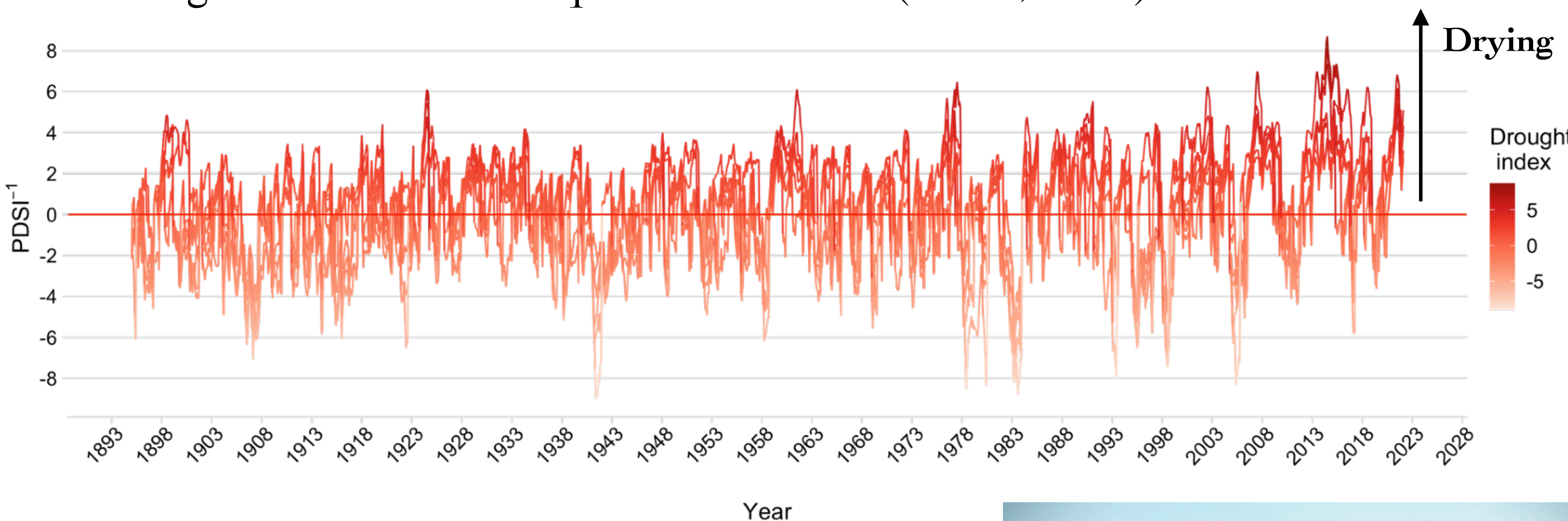

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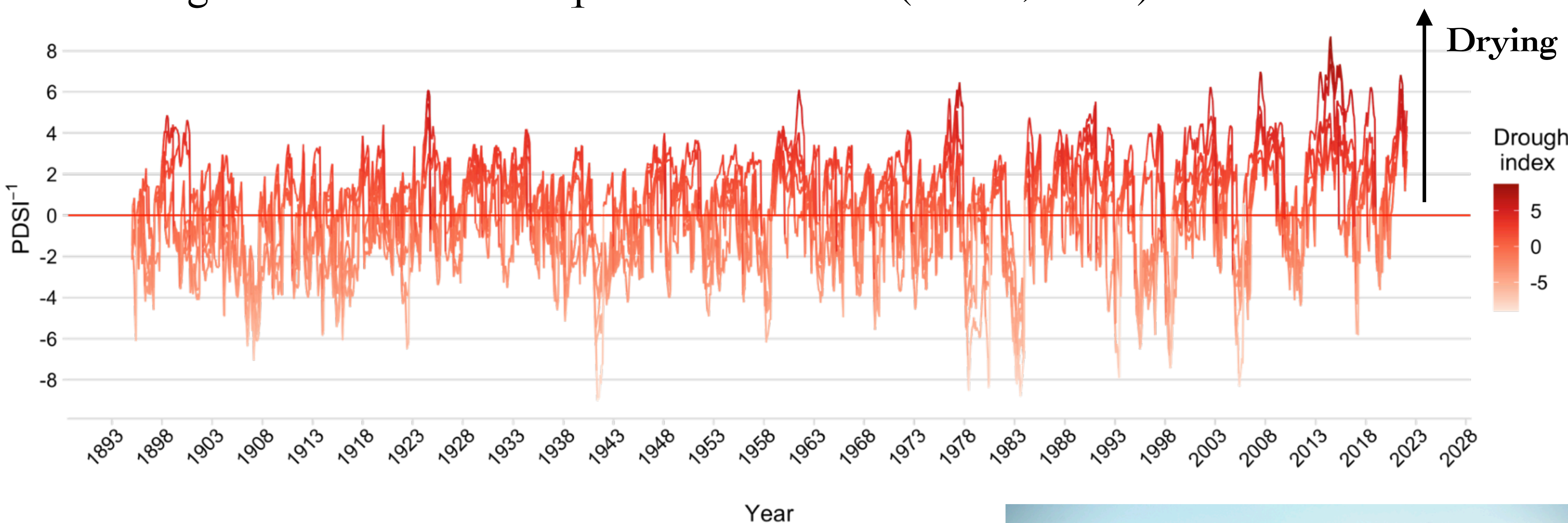

- Economic costs of drought
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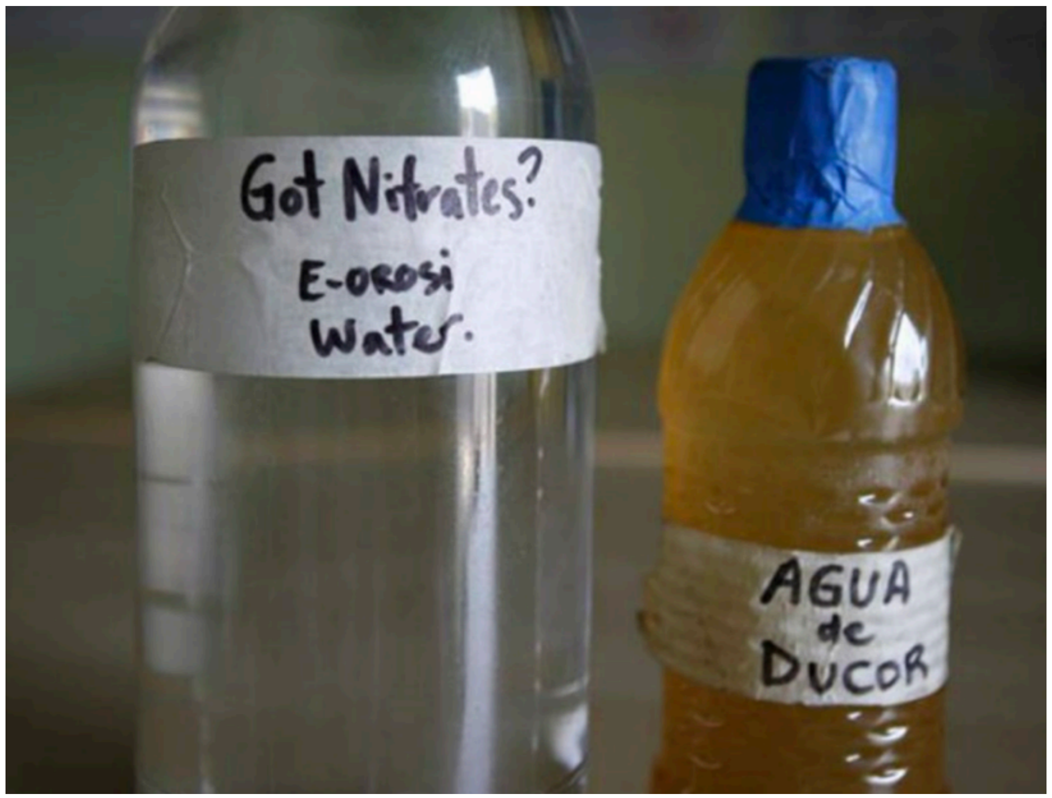
  - Heat related health and socioeconomic costs
  - Changes in **drinking water quality**

Credit: Gregory Urquiaga/UC Davis

Defining drinking water quality



Source: Community Water Center

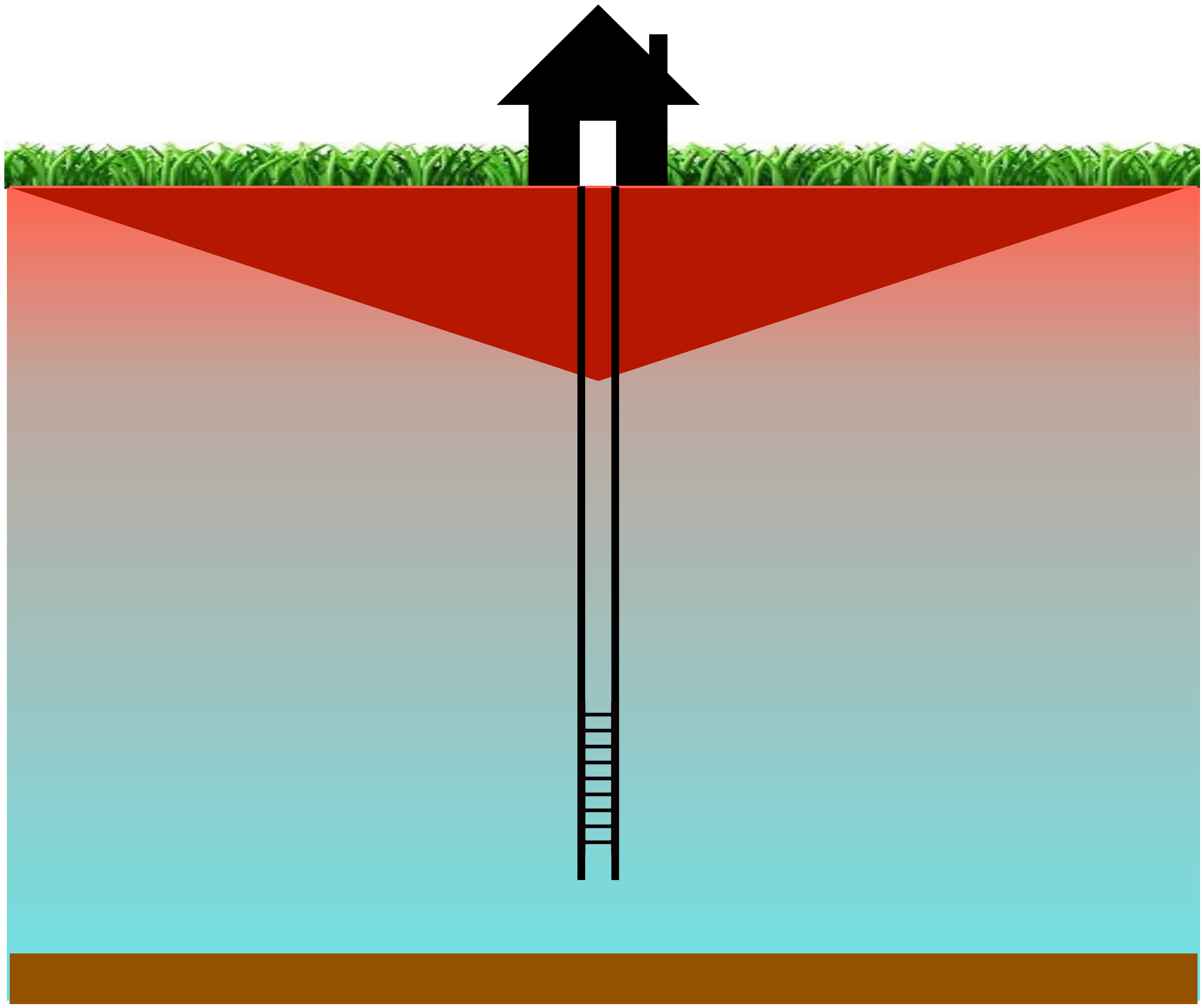
Nitrates (MCL: 10mg/l)

- 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

Mechanisms for drought's impact on groundwater quality



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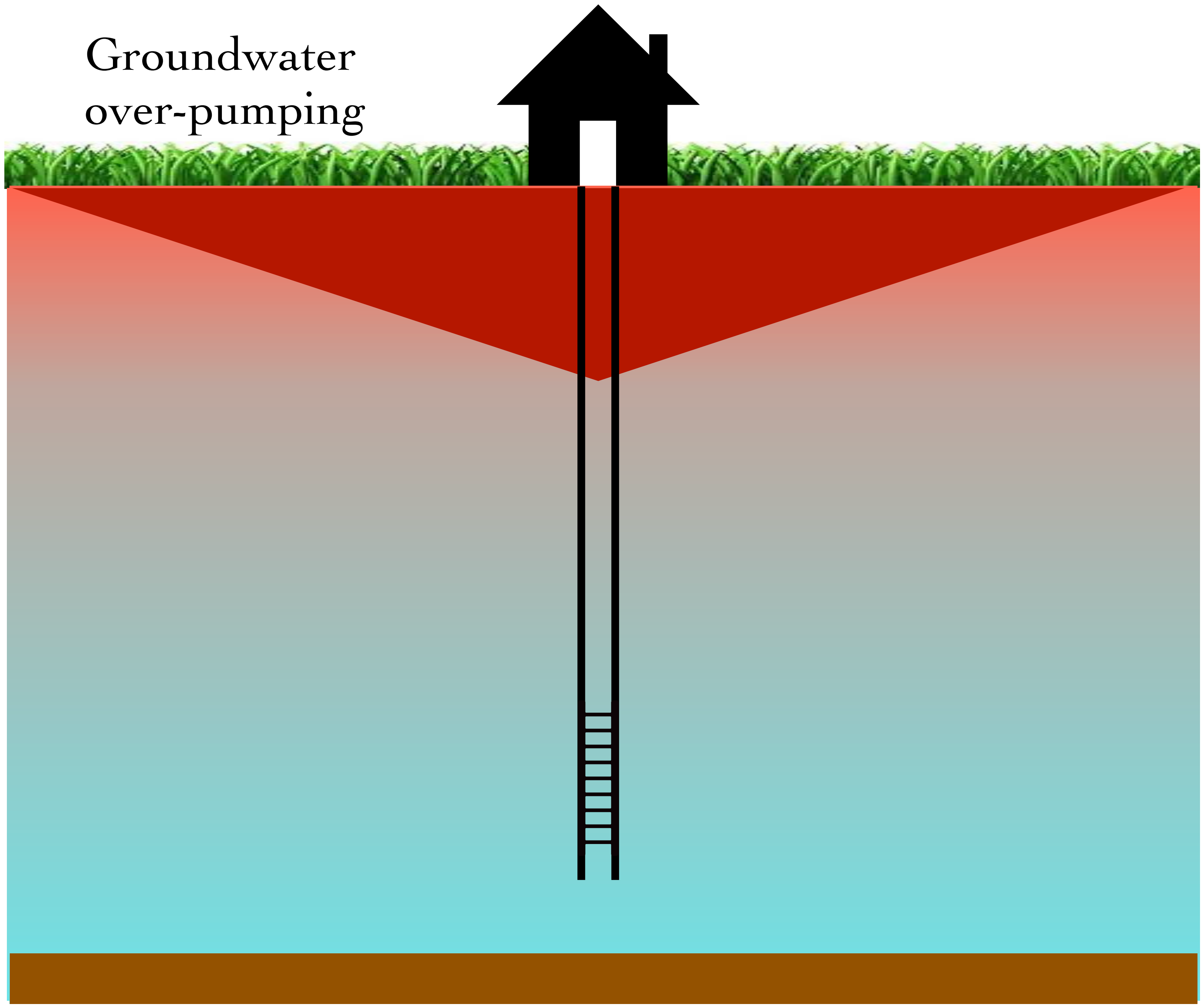

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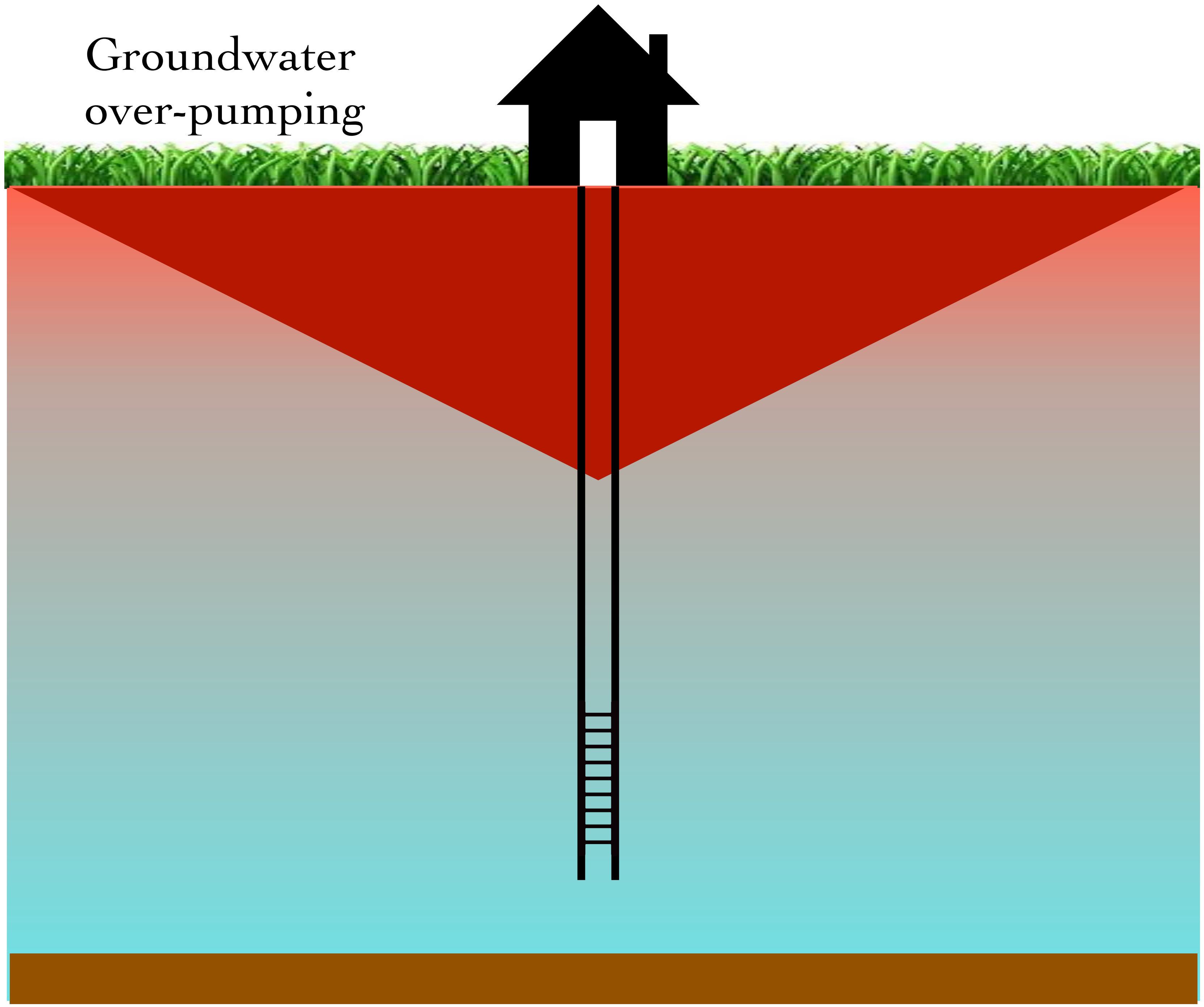

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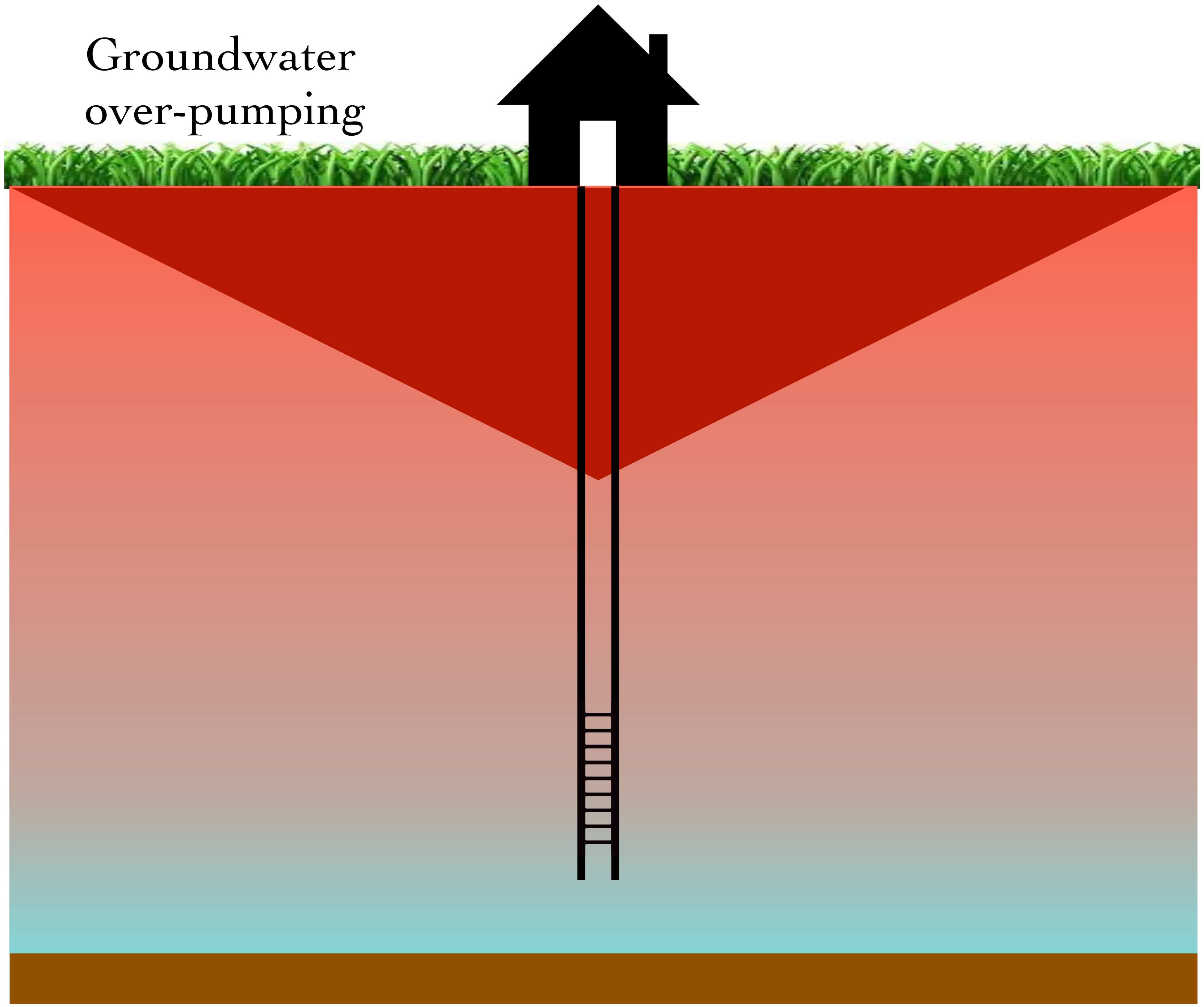

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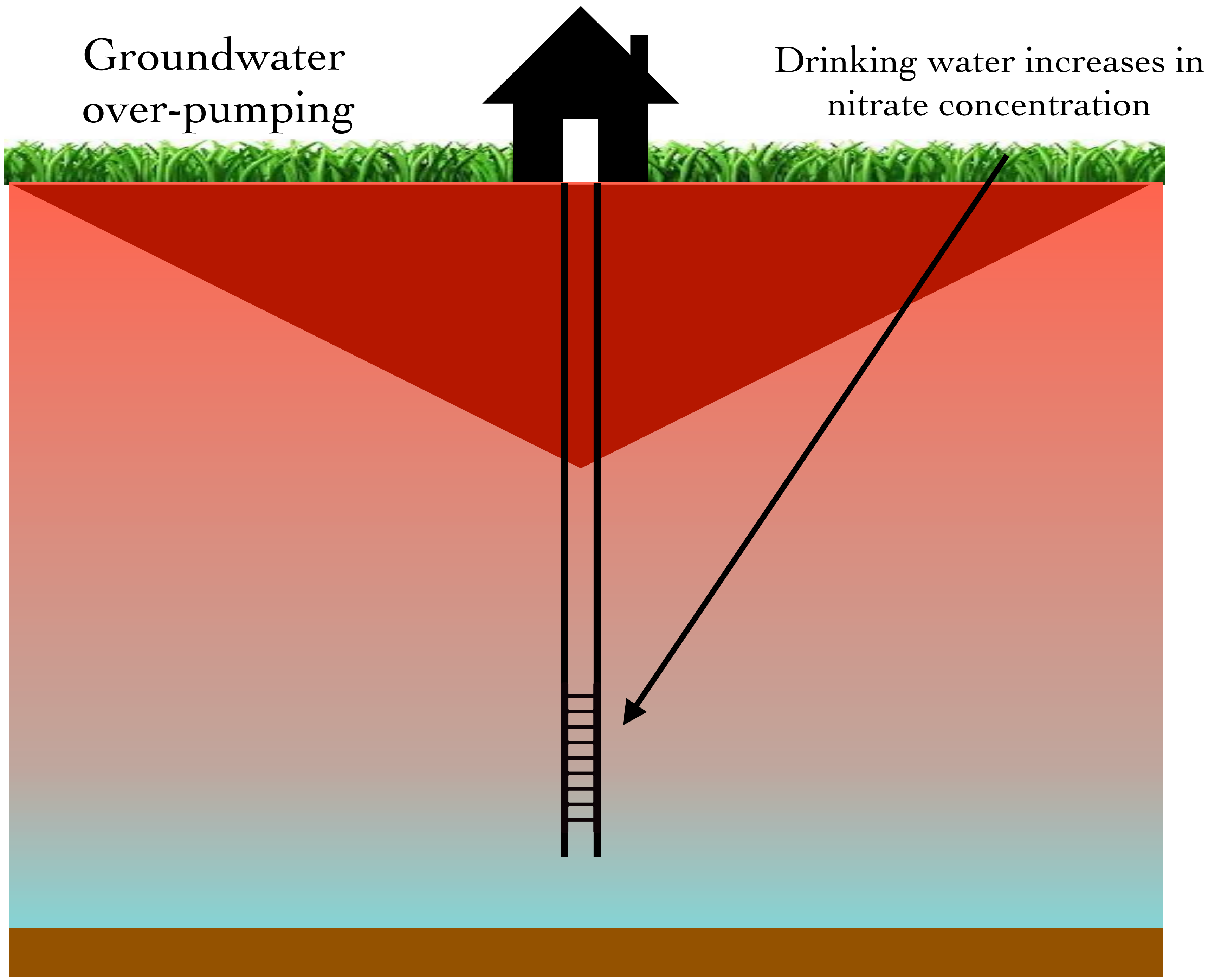

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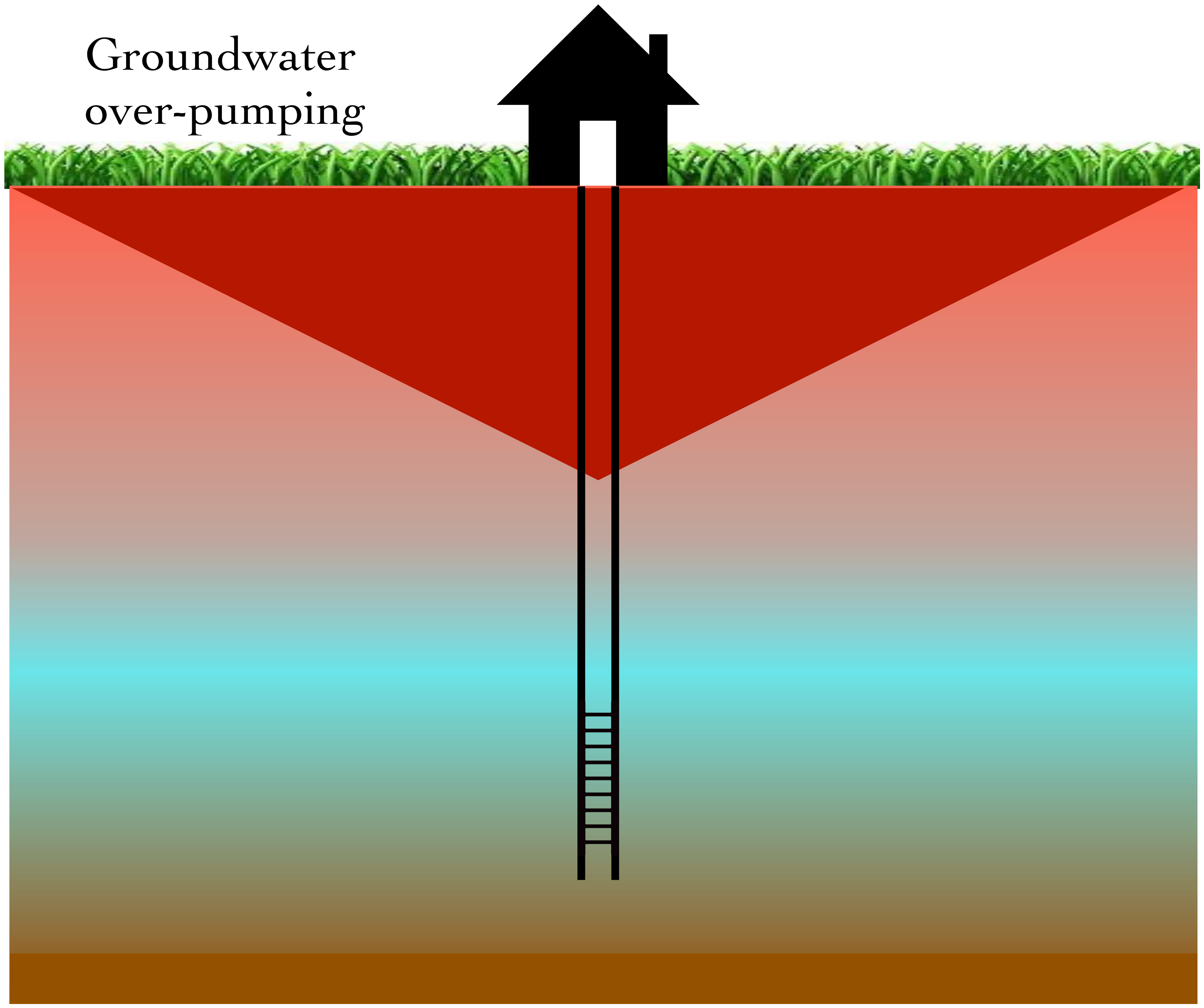

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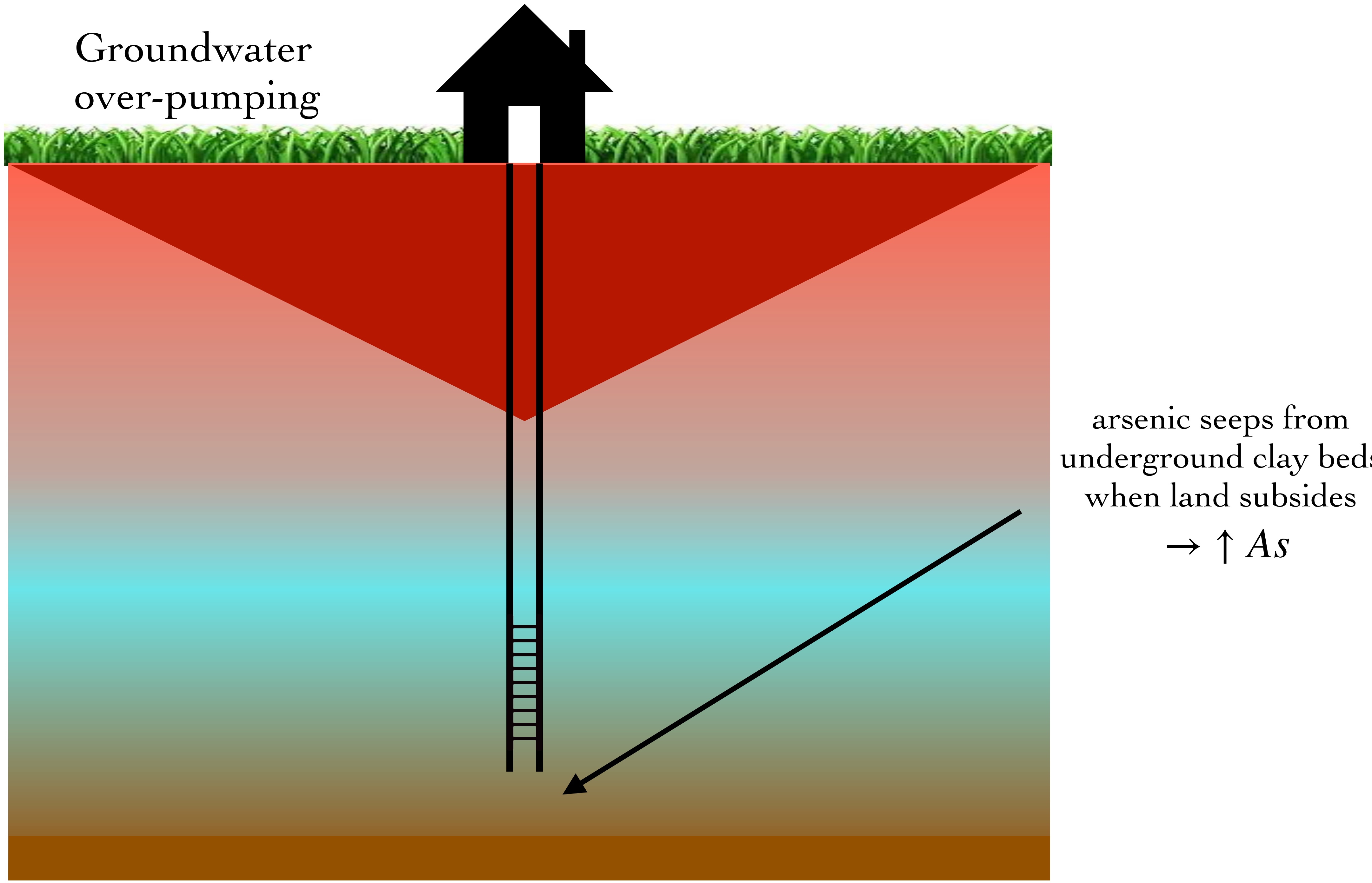

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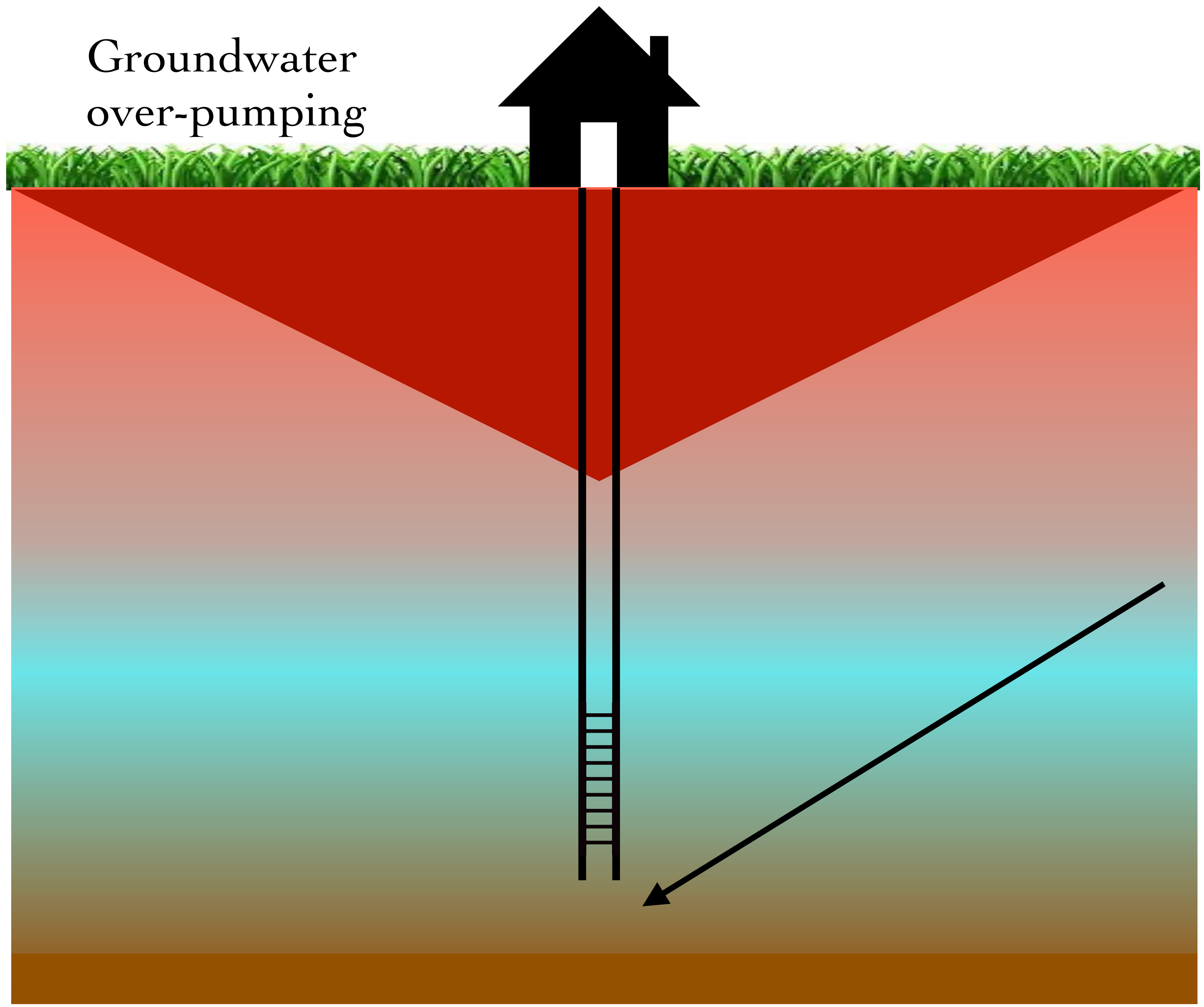

Mechanisms for drought's impact on surface water quality

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Temp ↑, As mobilizes and ↑

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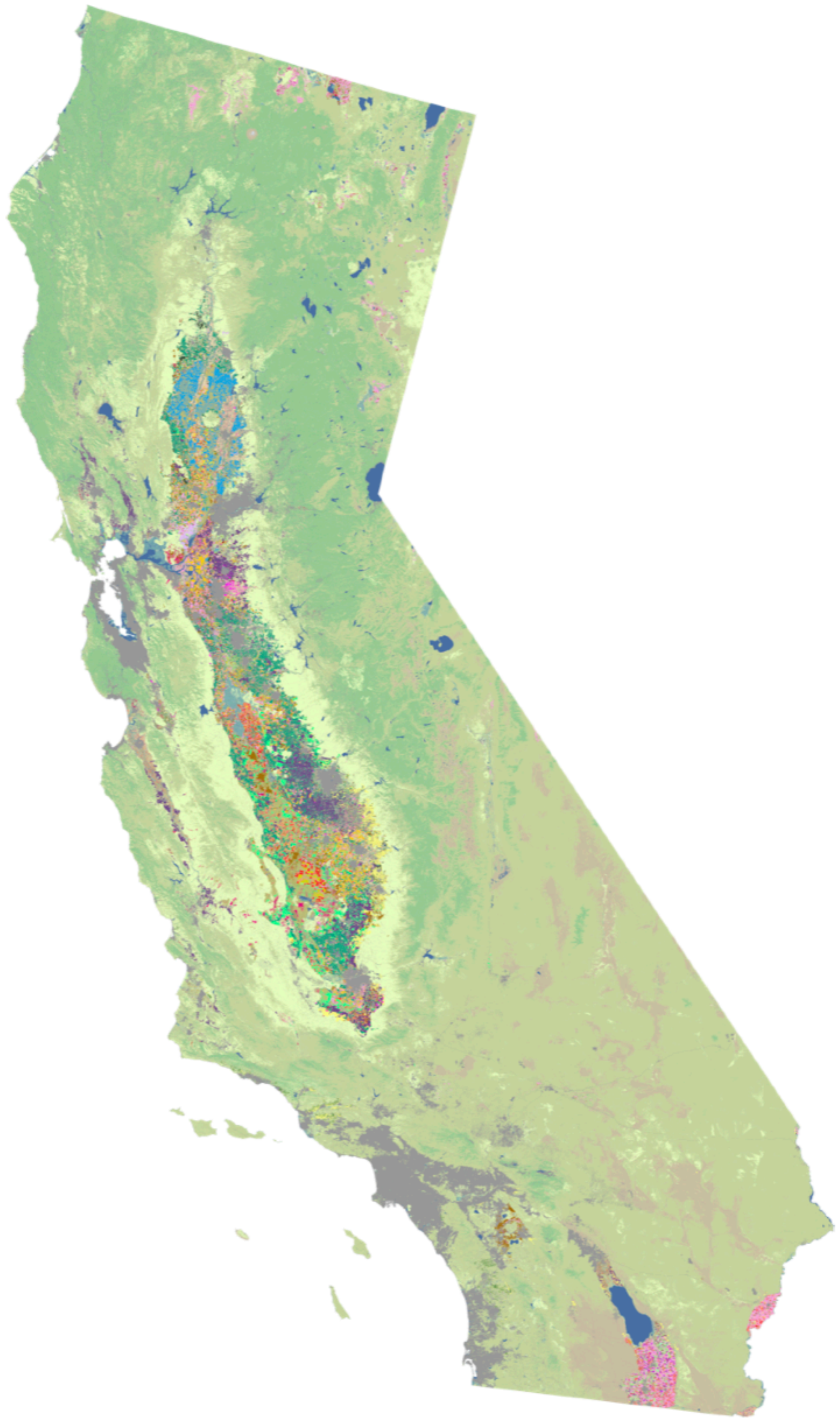
Drop in precipitation also leads to increasing concentration of contaminants

California and drinking water contamination



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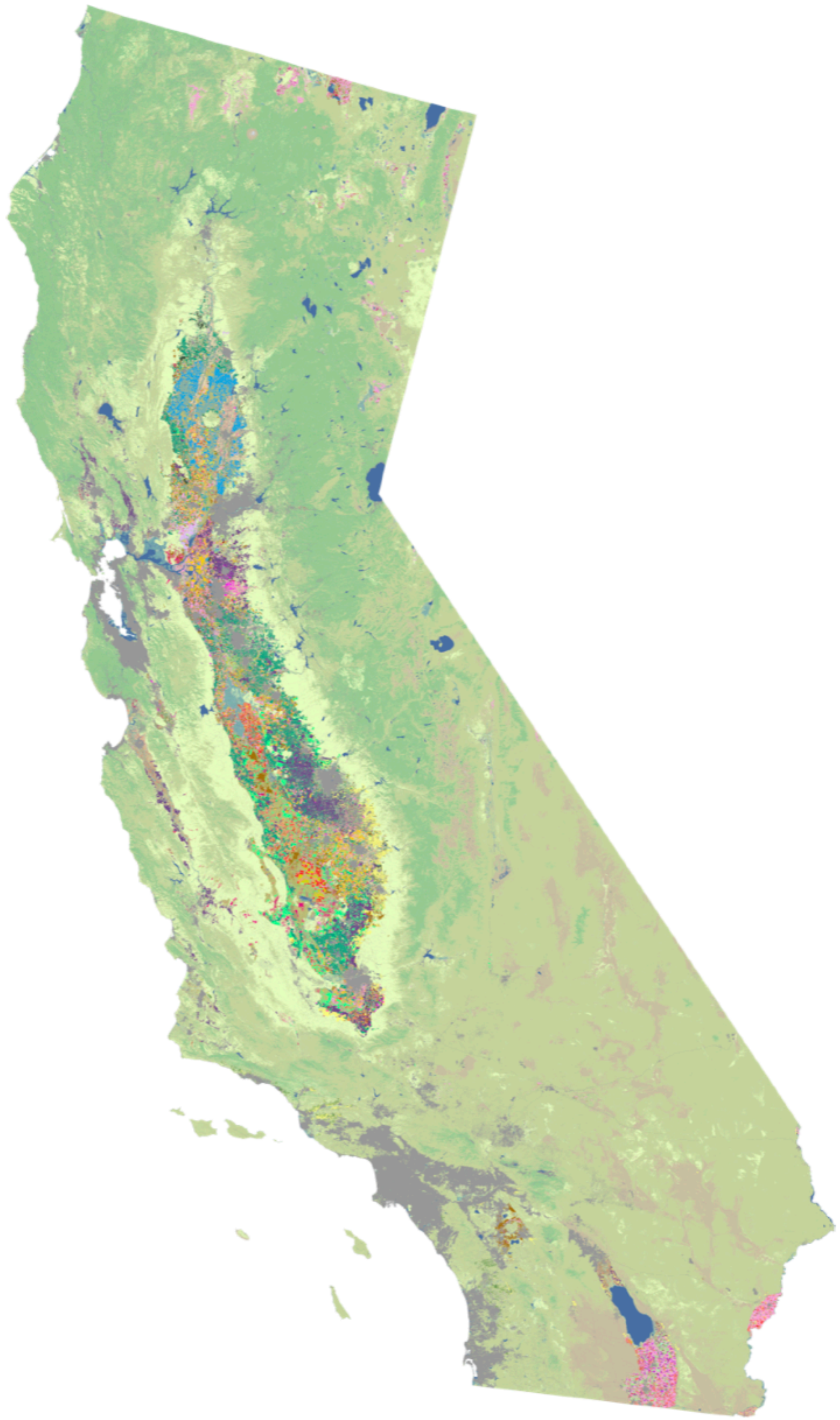

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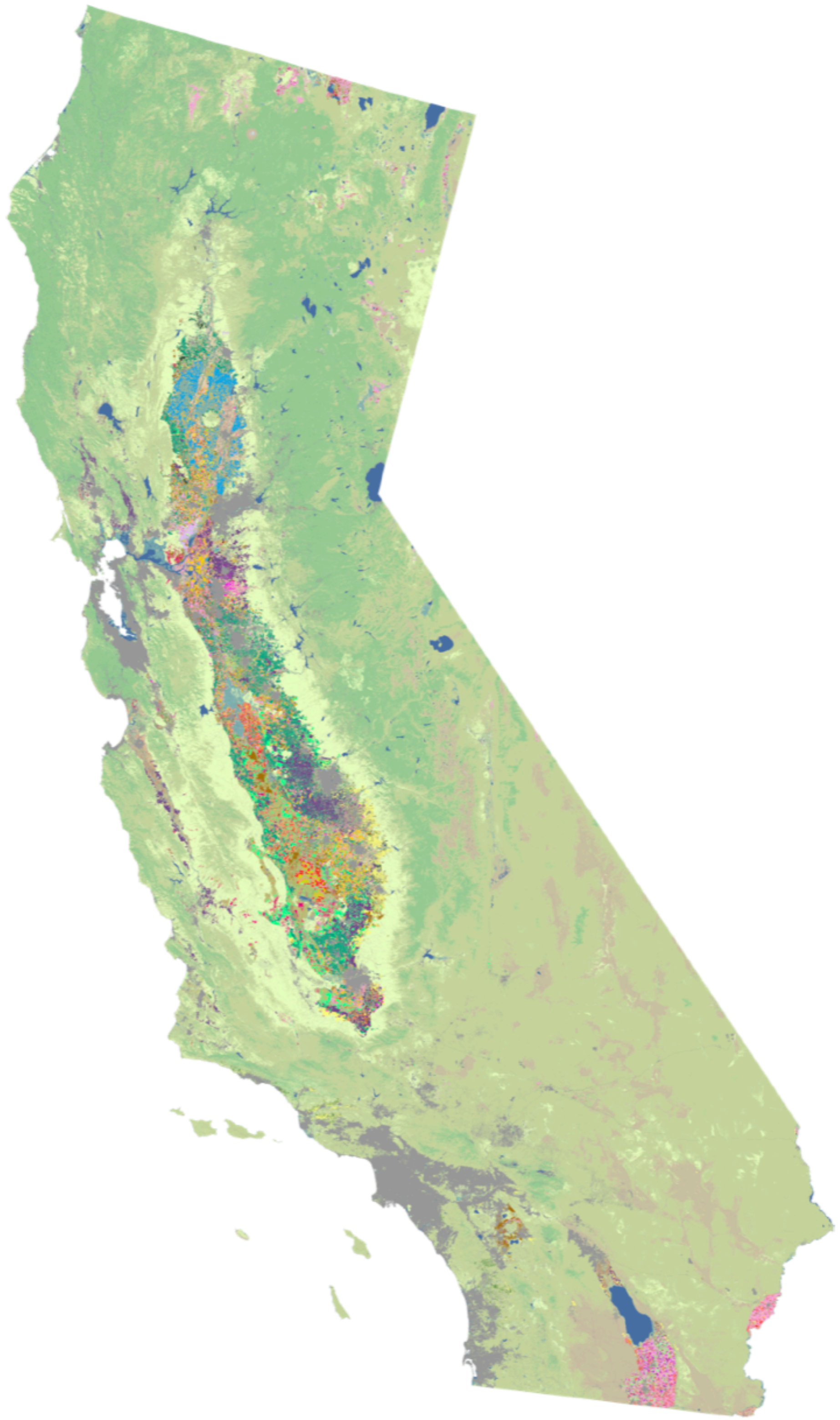

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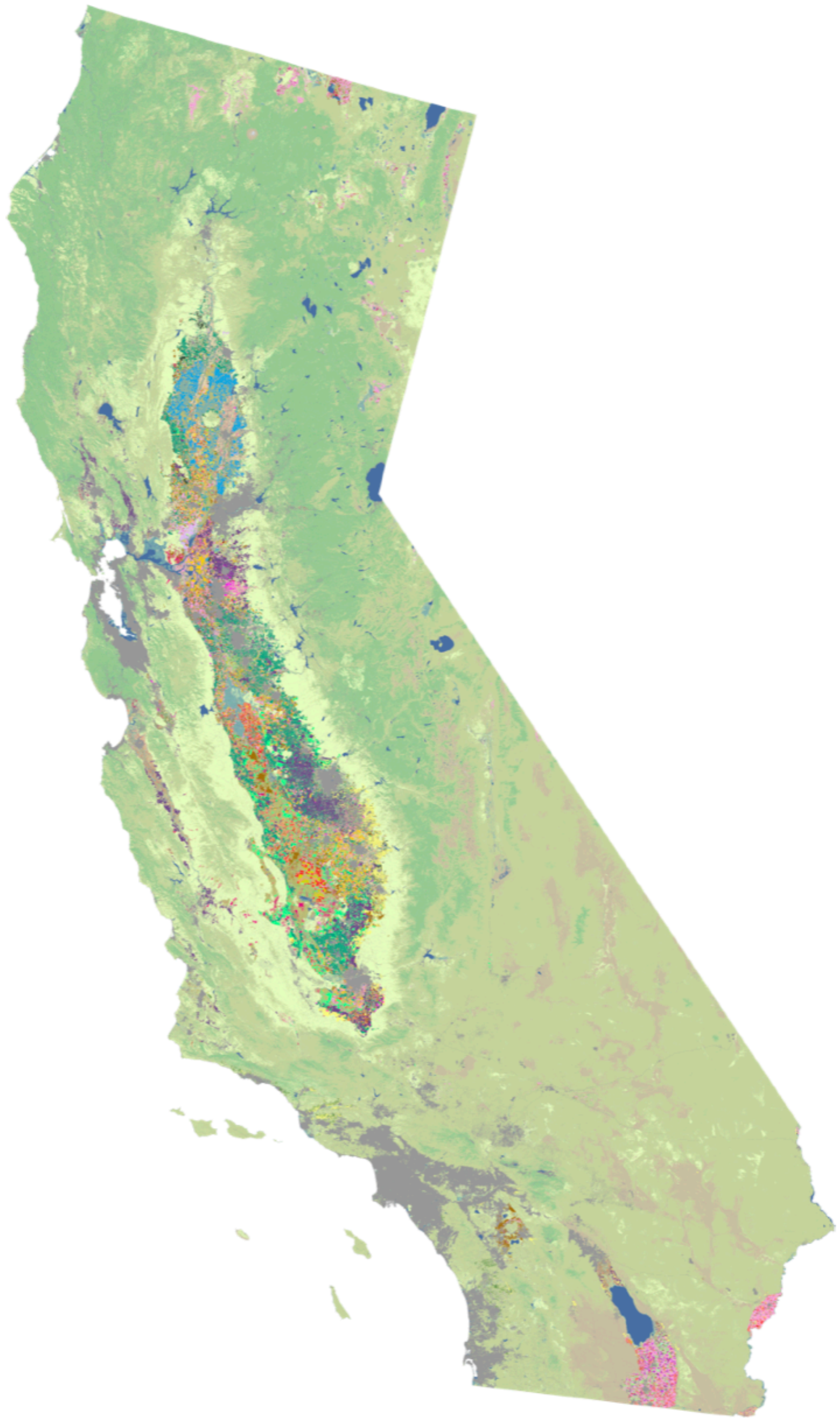

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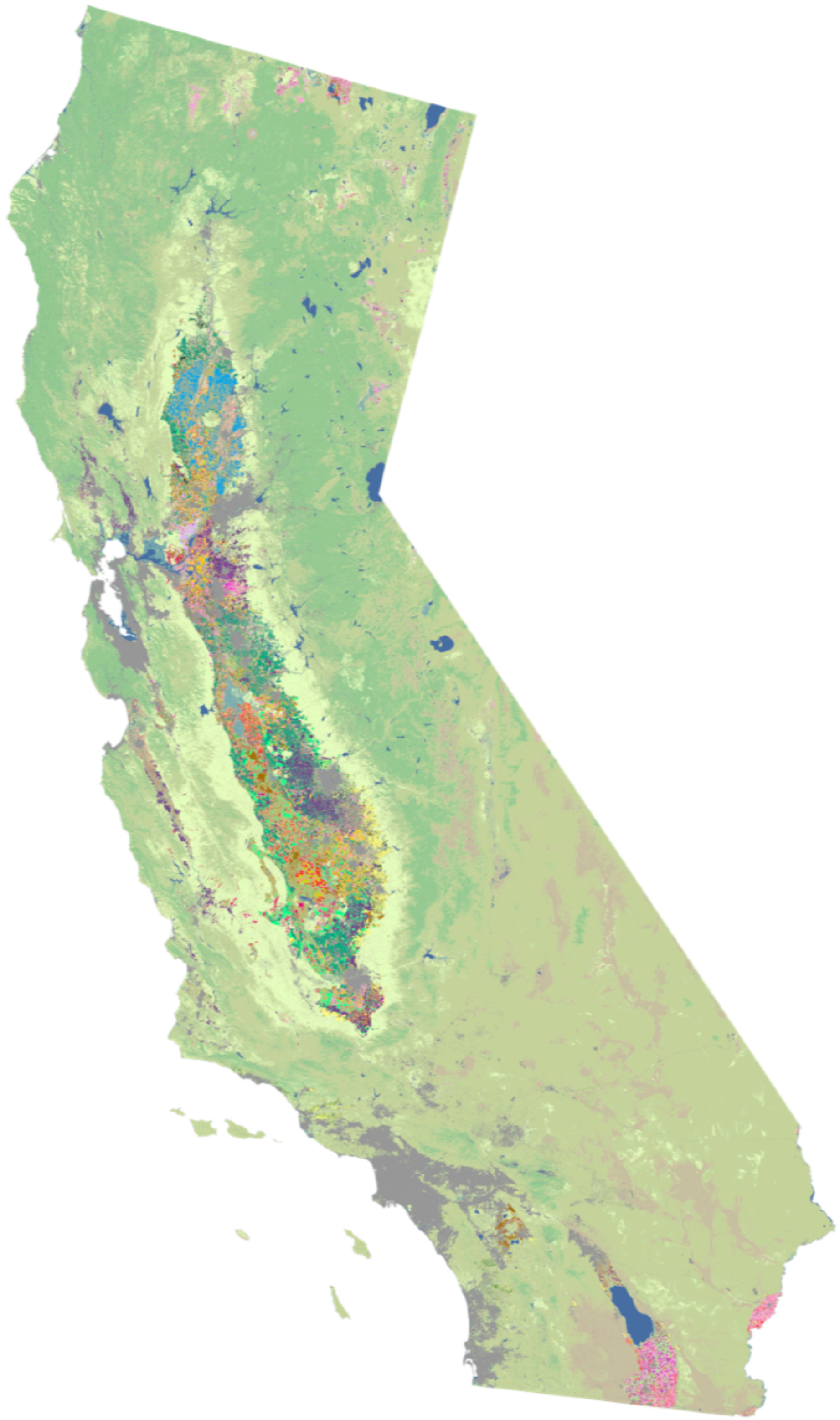

- Drought is severe
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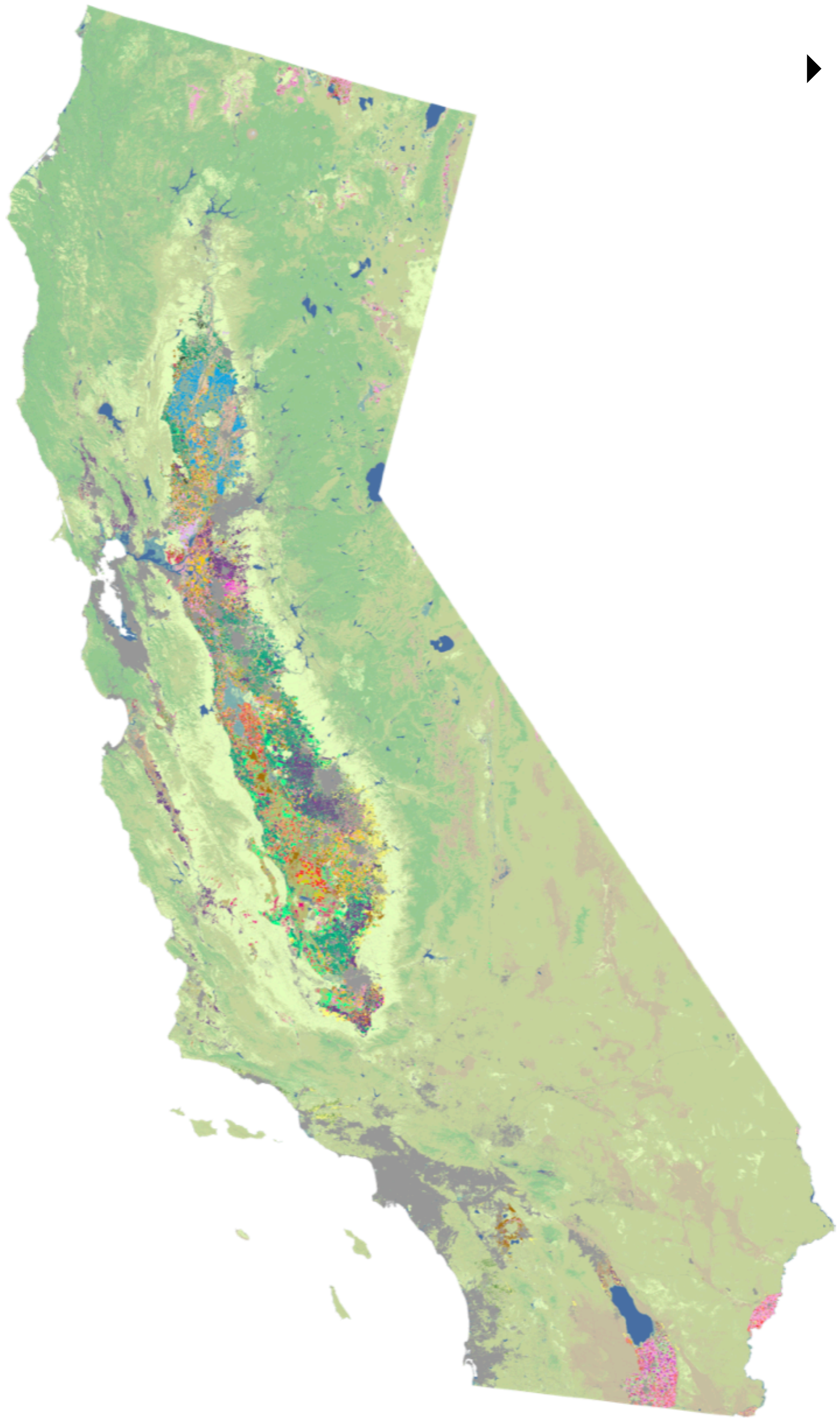
  - Agriculture → nitrate pollution
  - Drought → groundwater pumping

Equity implications



- Who lives in places vulnerable to drought effects?

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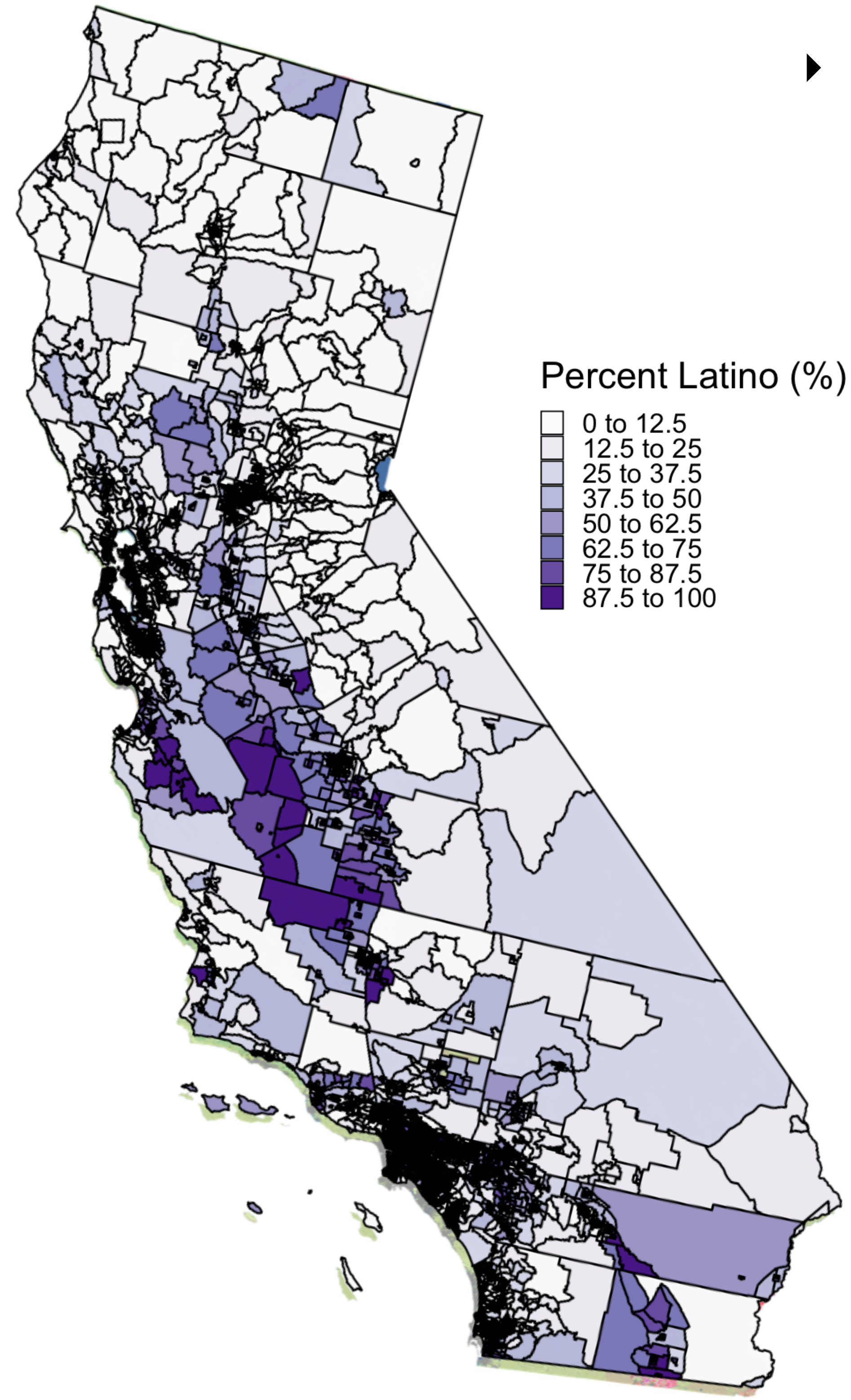

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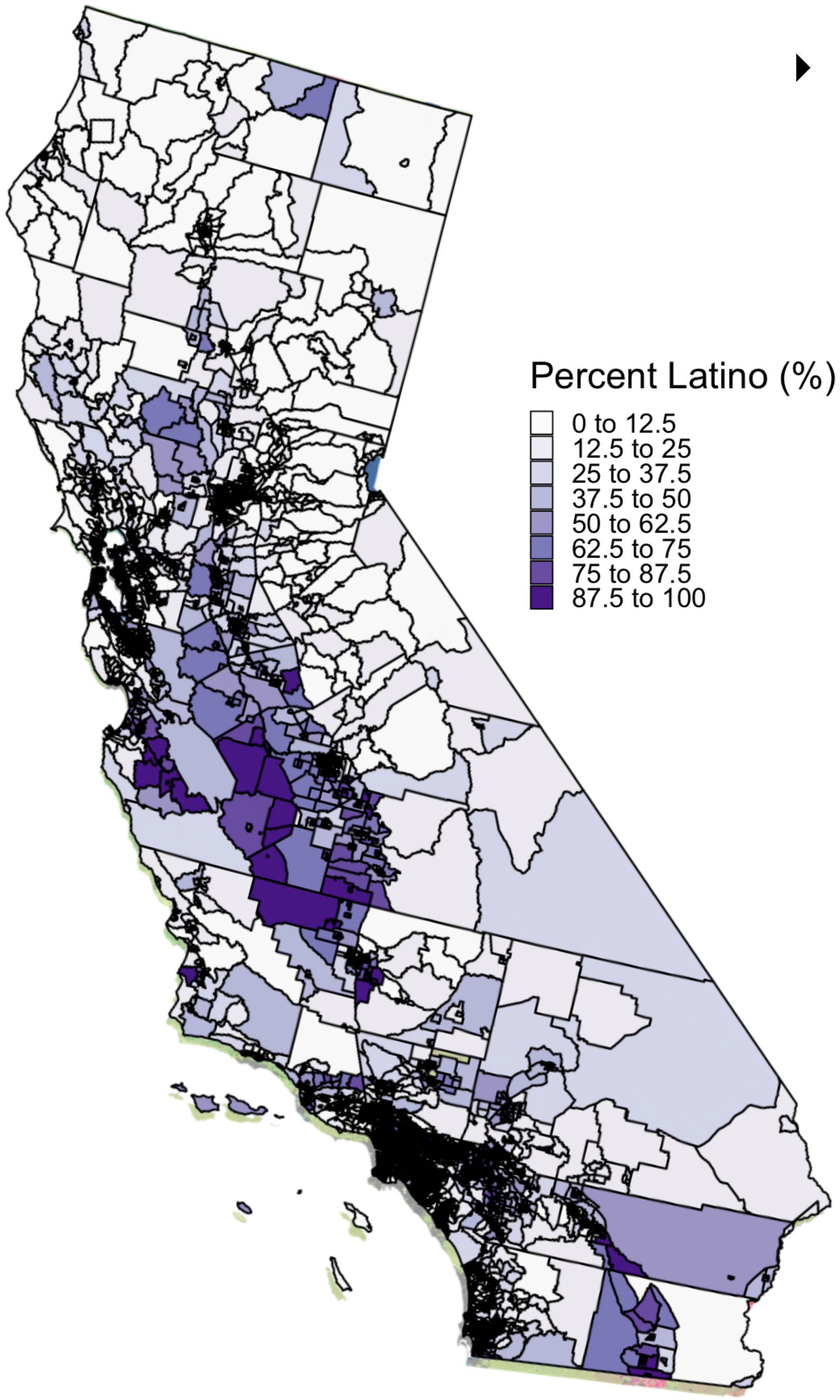

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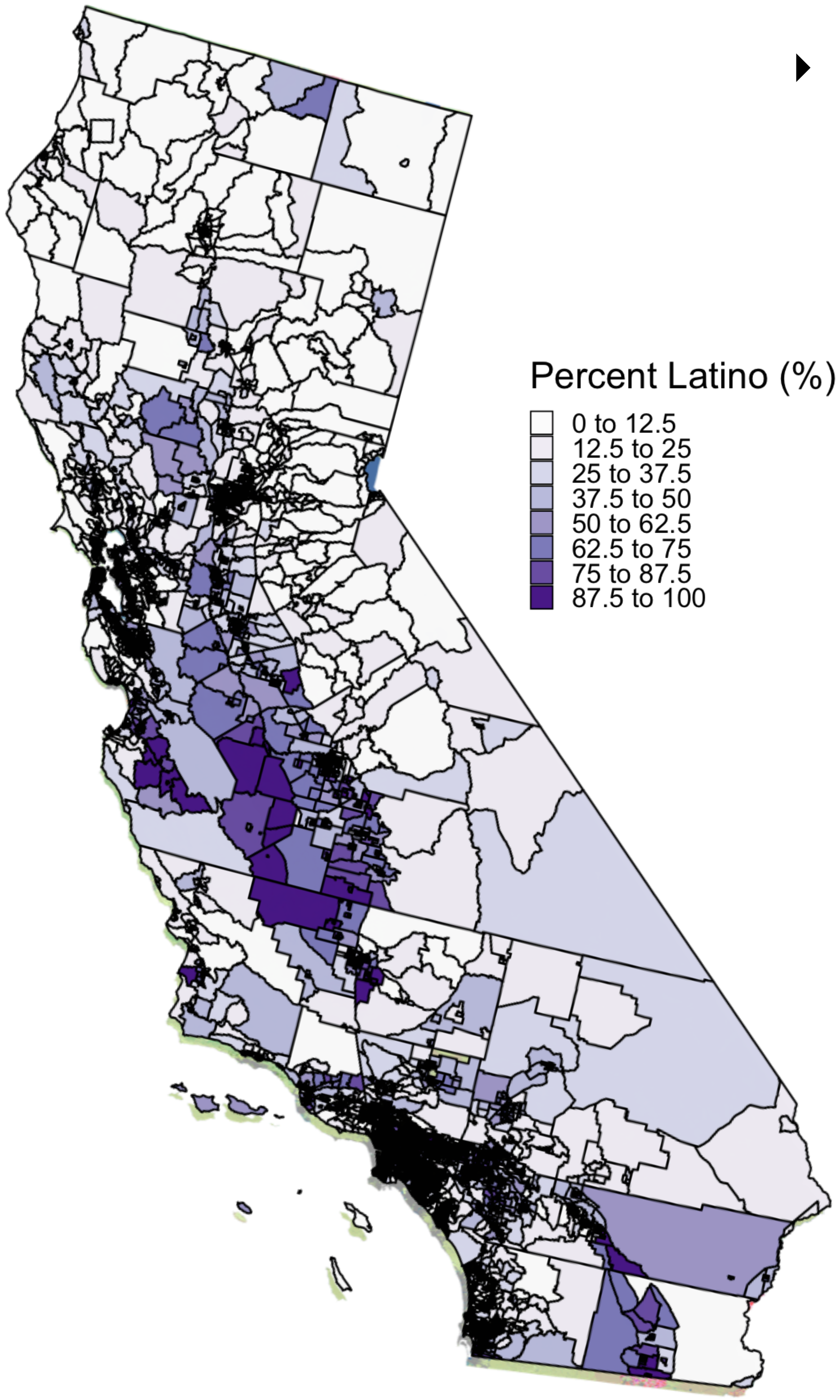

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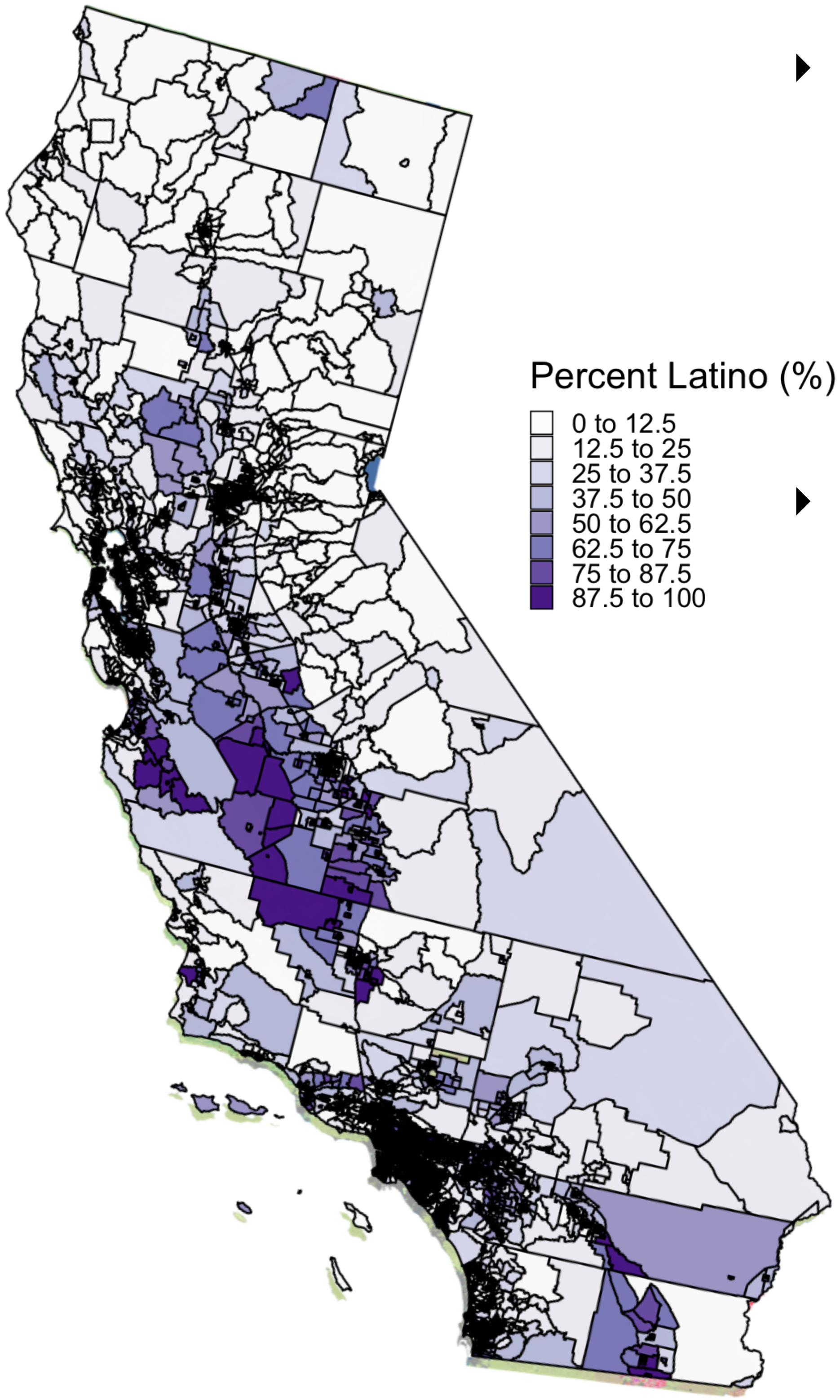

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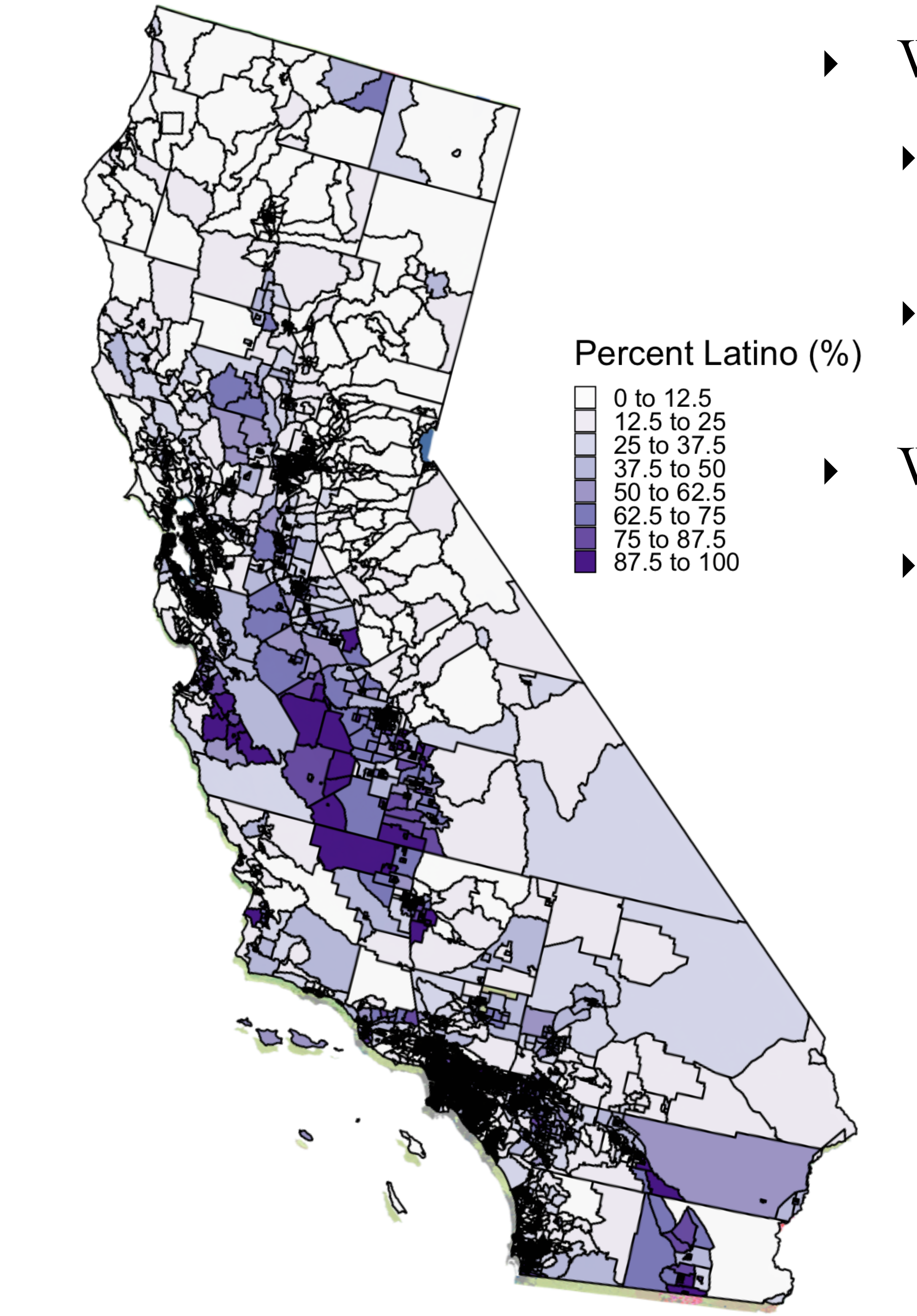

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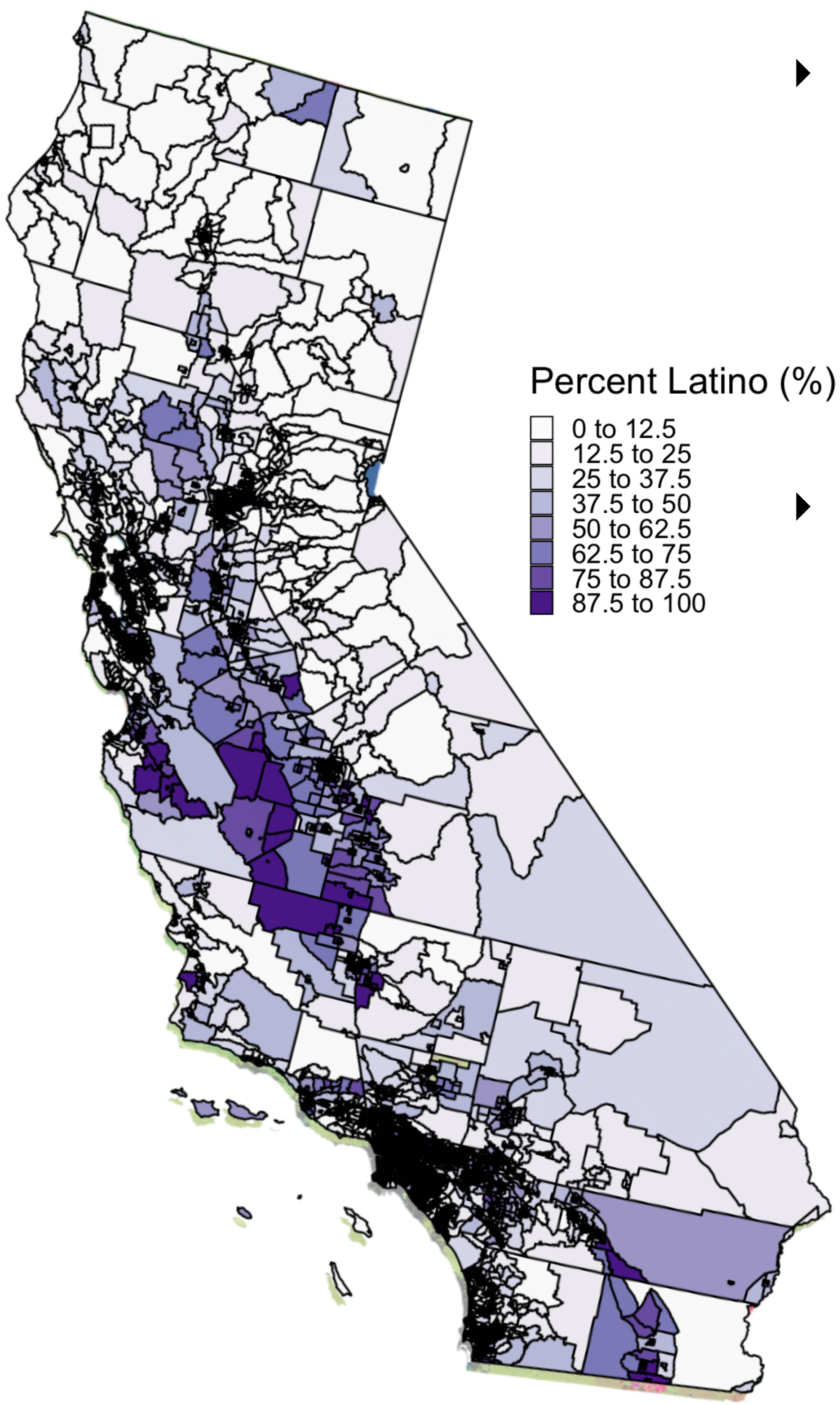

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  - Impacted communities incur adaptation or health costs

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)

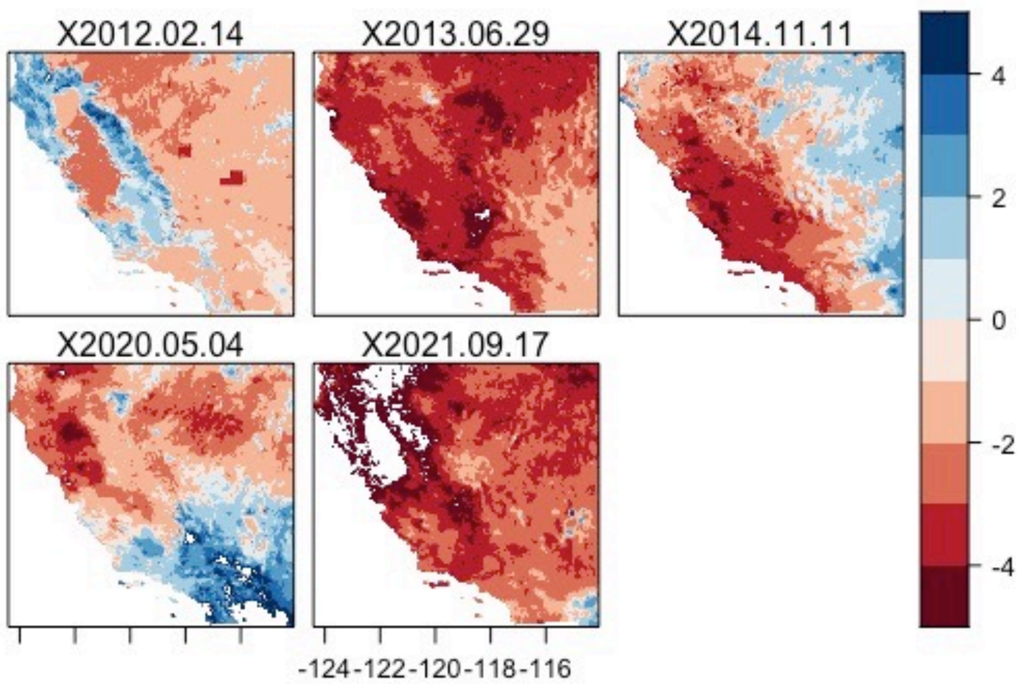
- **Qualitative evidence**

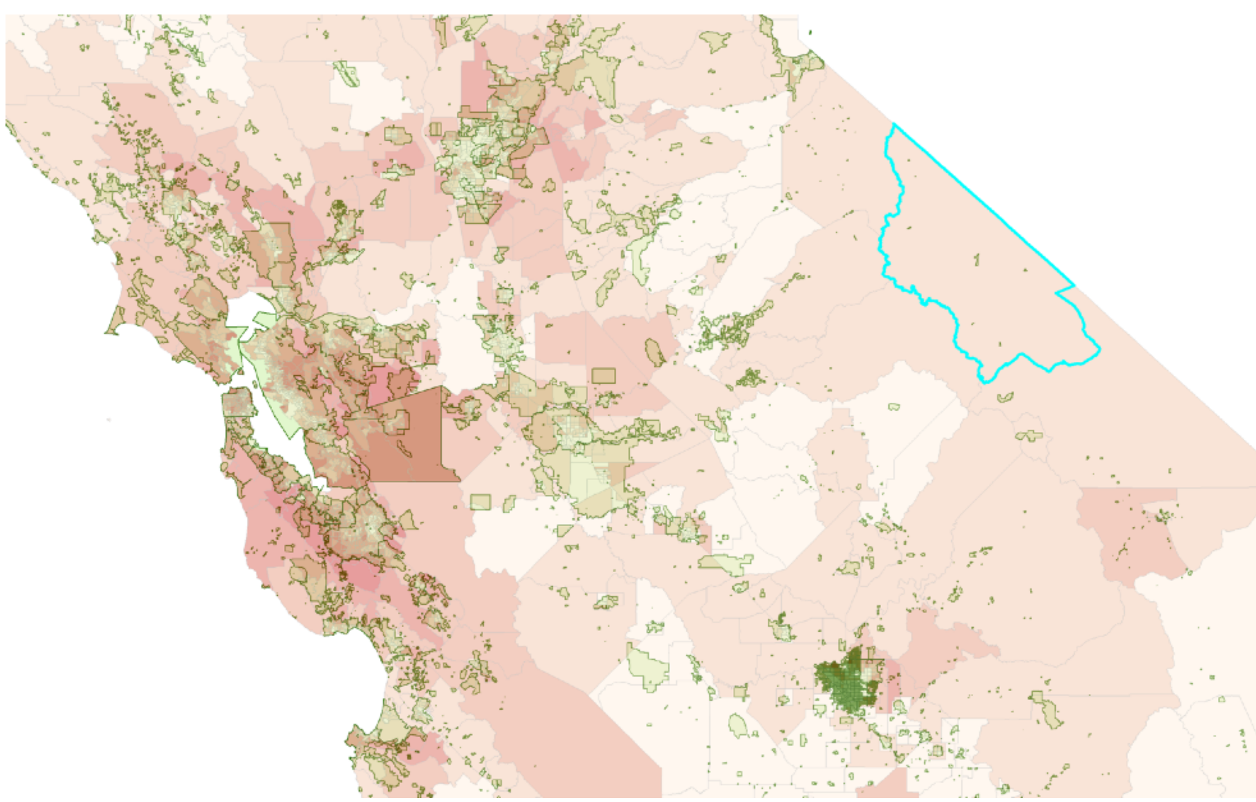
  e.g. New York Times (2011, 2012, 2019); The Washington Post (2019)

- **Costs of groundwater pumping**

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

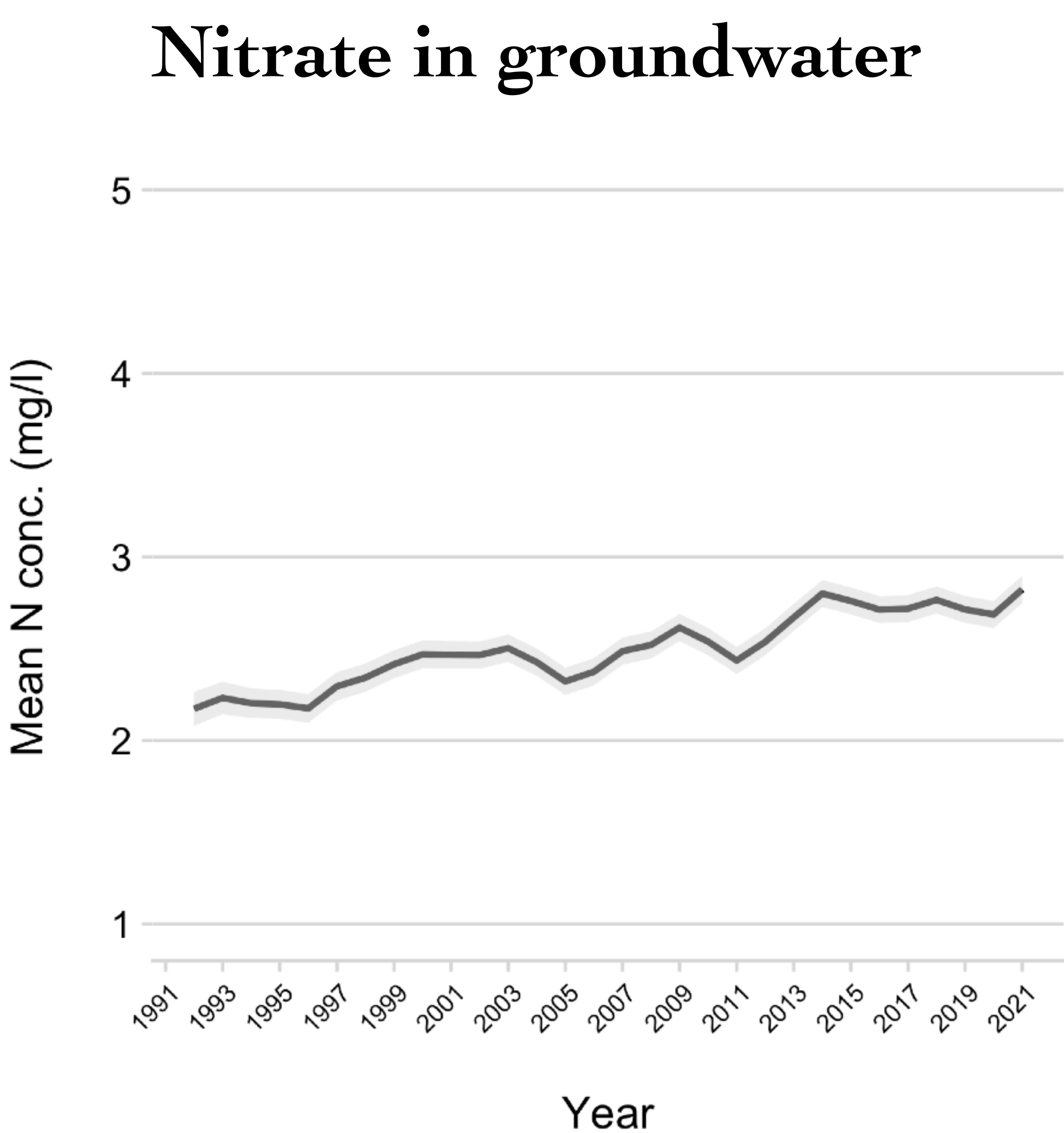
Data





- **CA SWRB regulatory water monitoring data**
    - Sample point **within** distribution system of water system
    - $i \in \{G, S\}$
- EPA ECHO SWDA PWS facility data
- Palmer Drought Severity Index
- **PWS service area boundary shapefiles**
    - + 2019 American Community Survey
    - + CA soil census
    - + USDA Crop Data Layer 2018
    - + CA well completion report

First glance at the data



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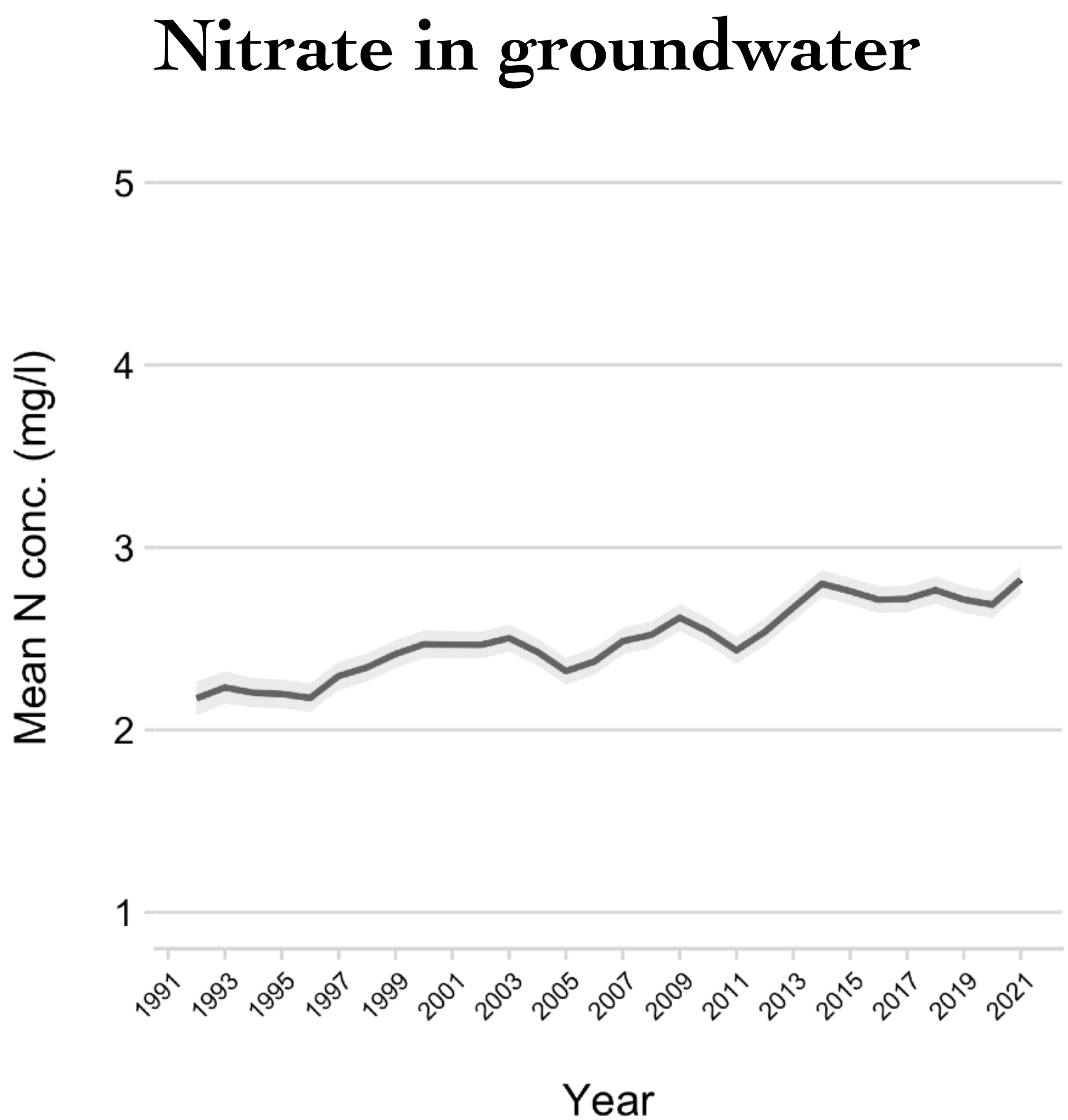

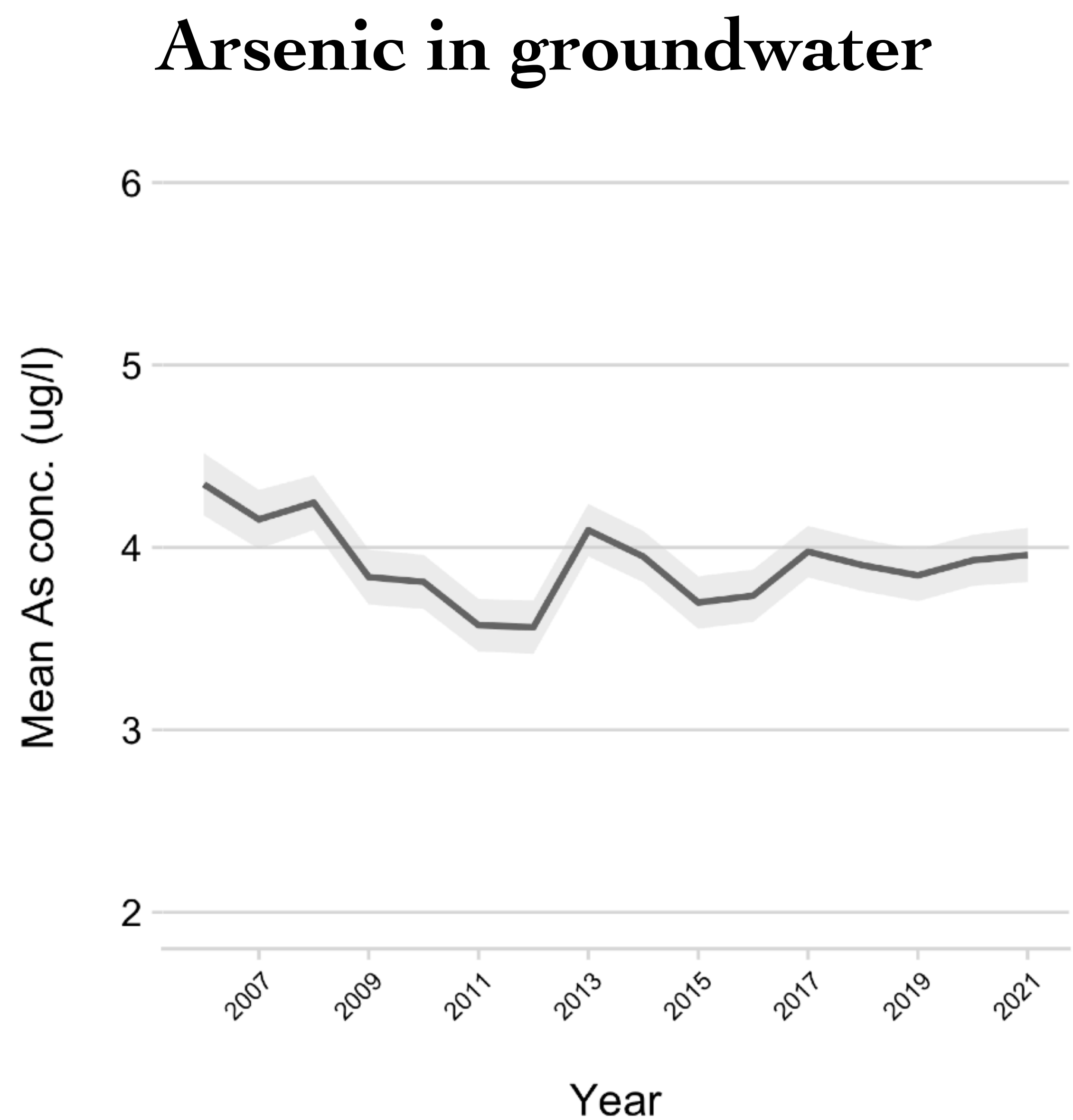

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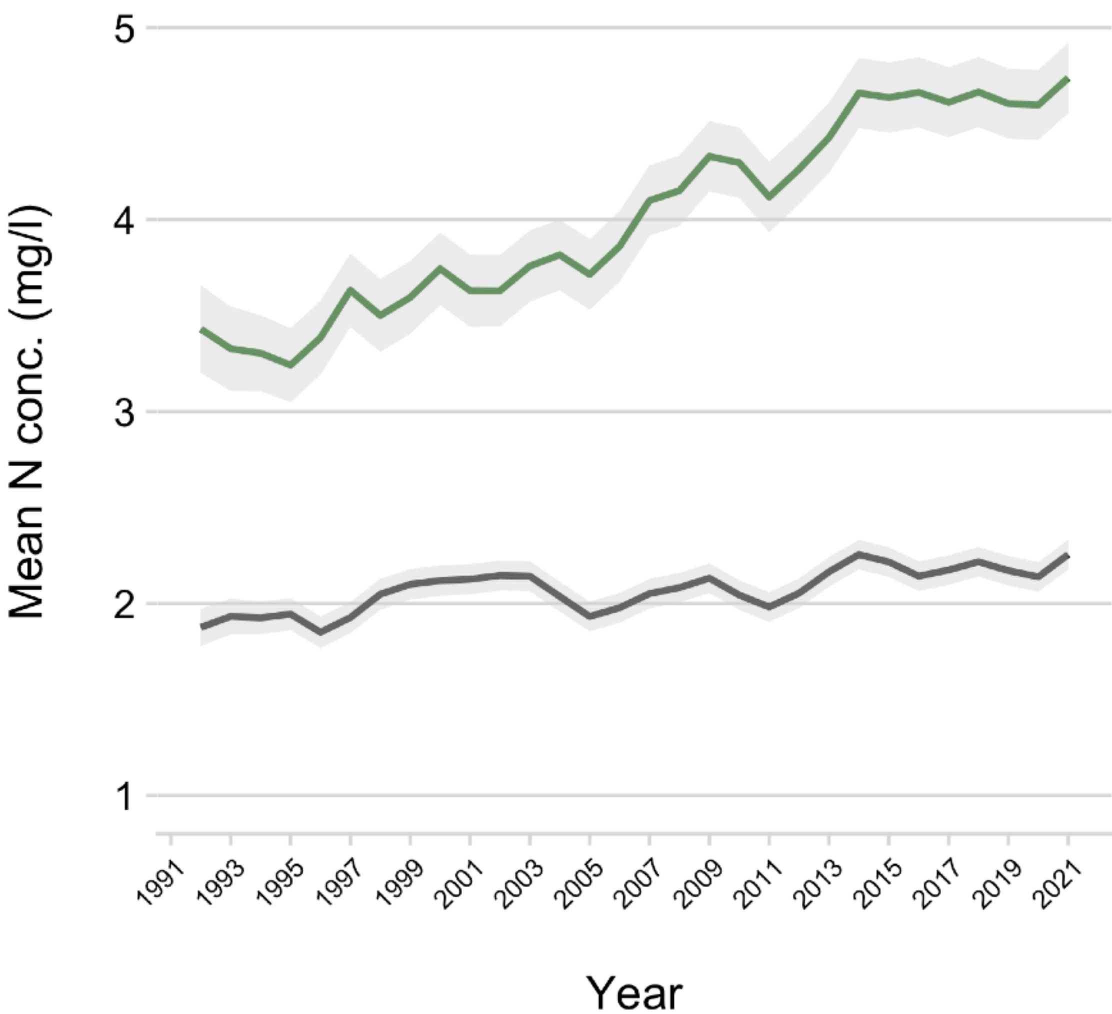
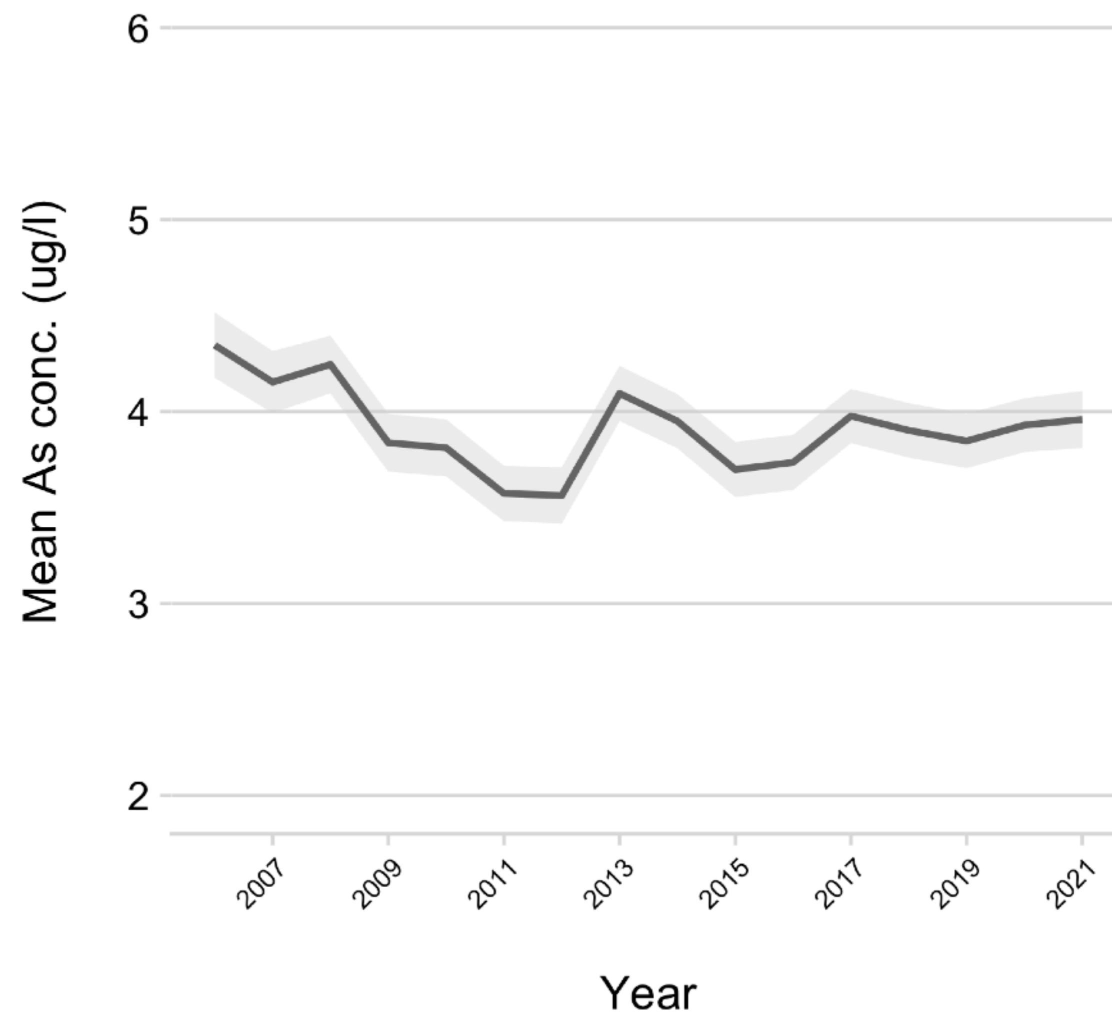
- All other
- Majority Latino

Nitrate in groundwater



Arsenic in groundwater



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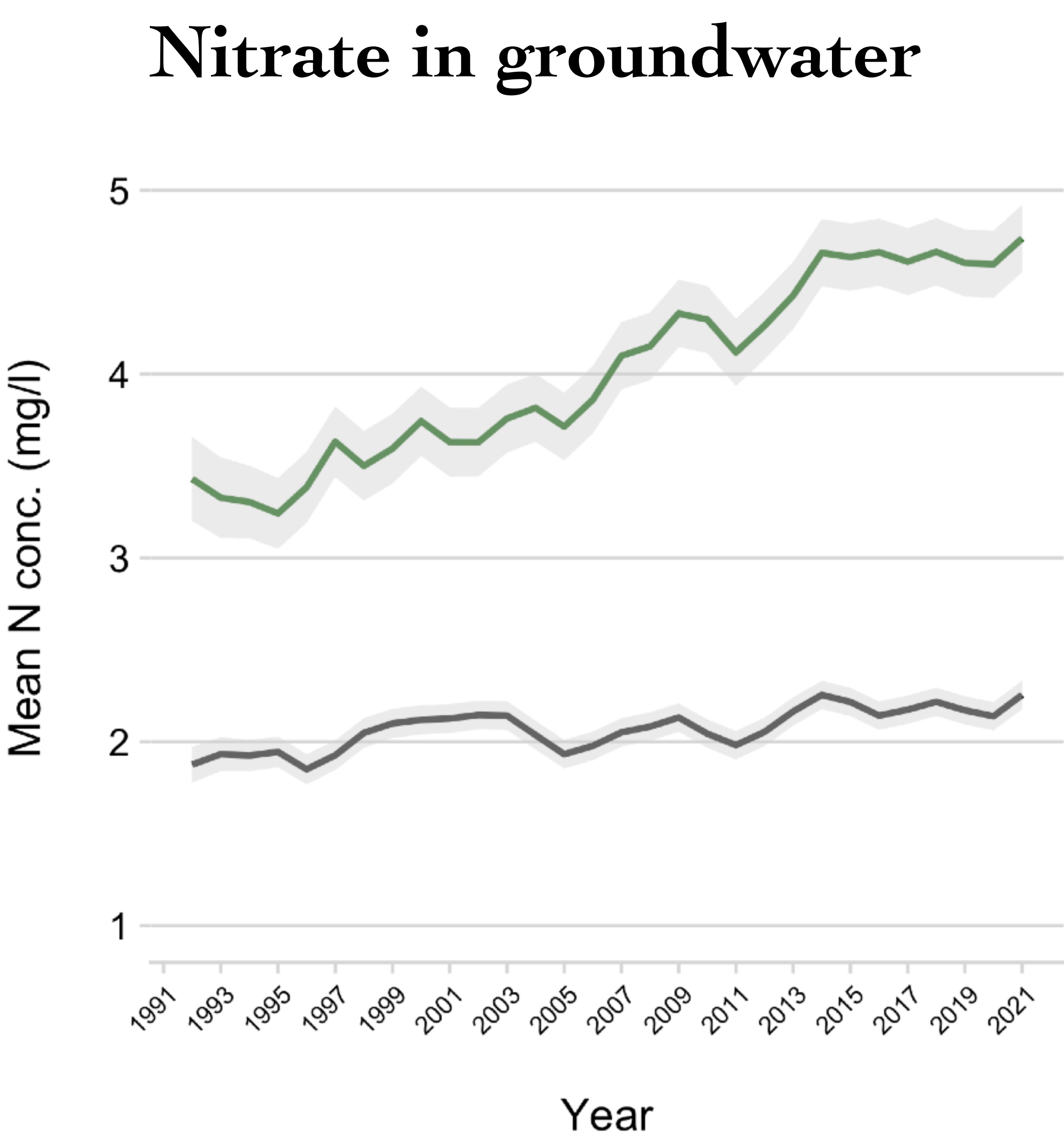

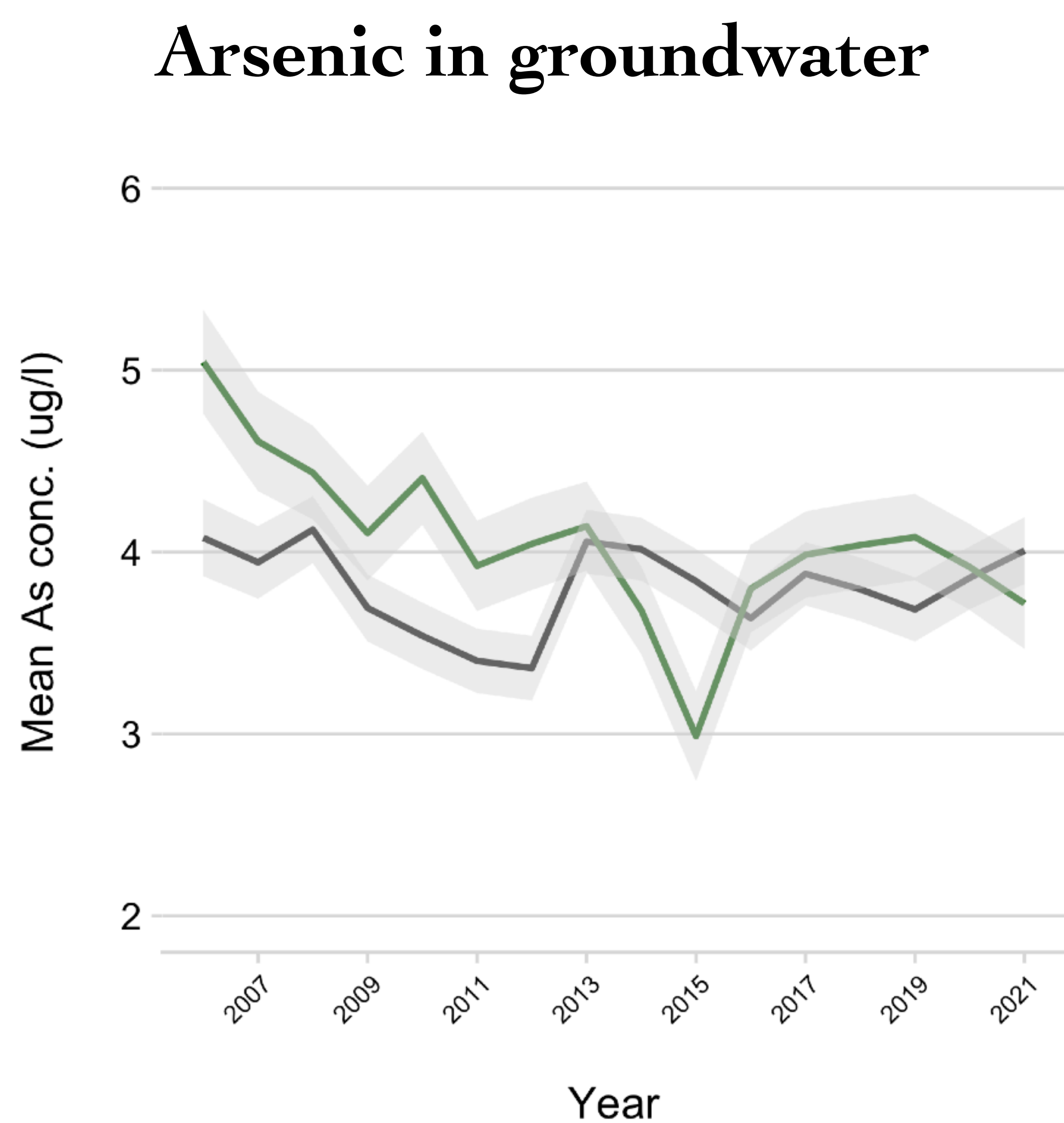

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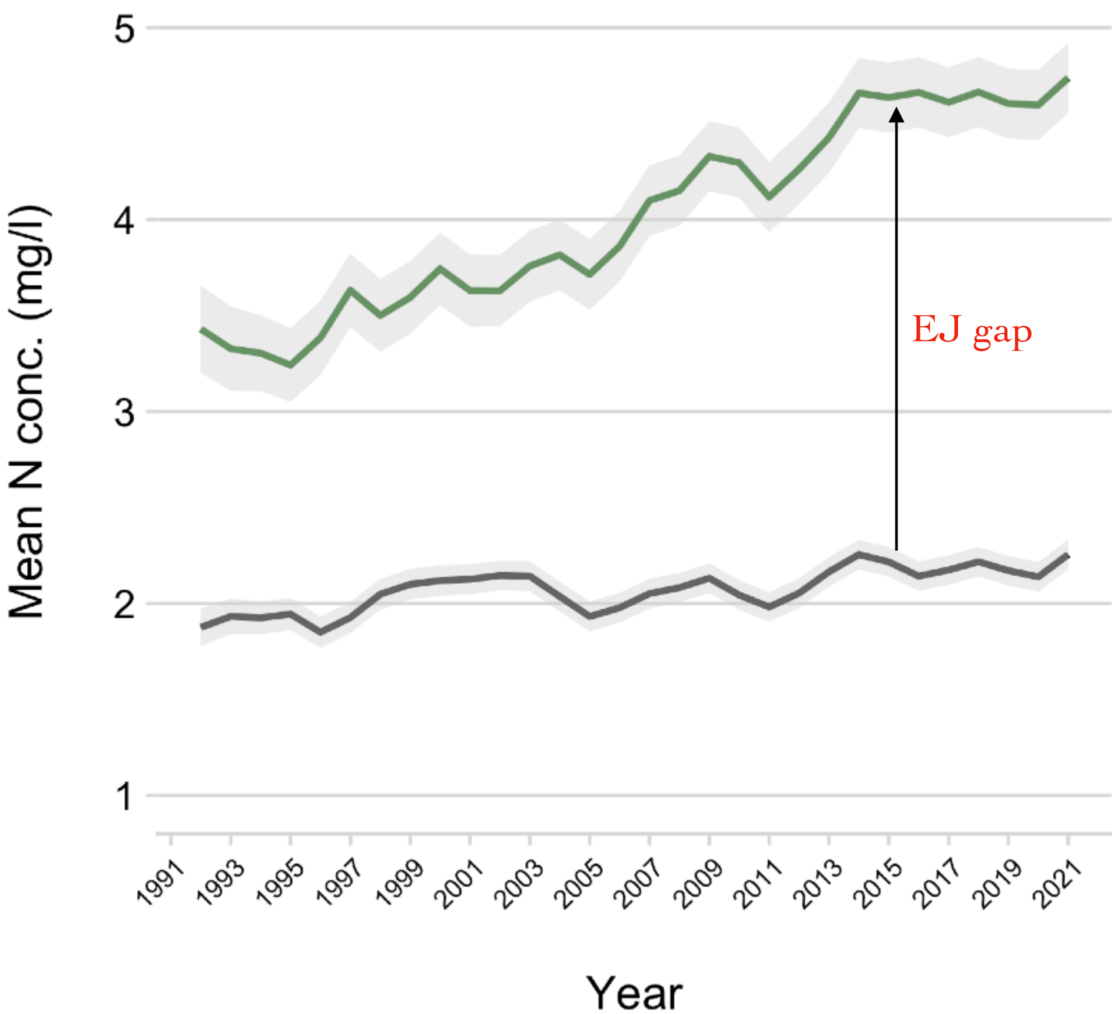

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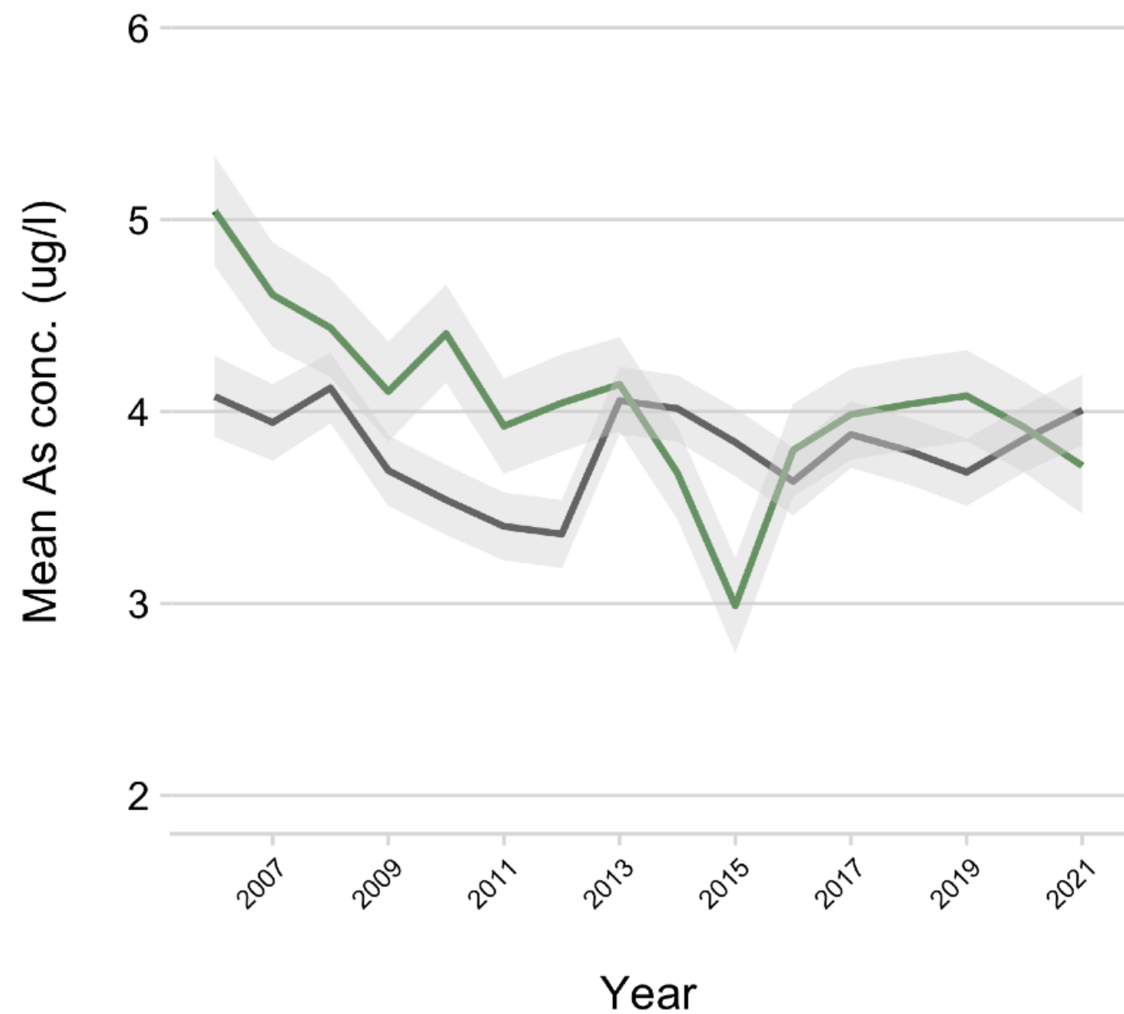

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Drought years

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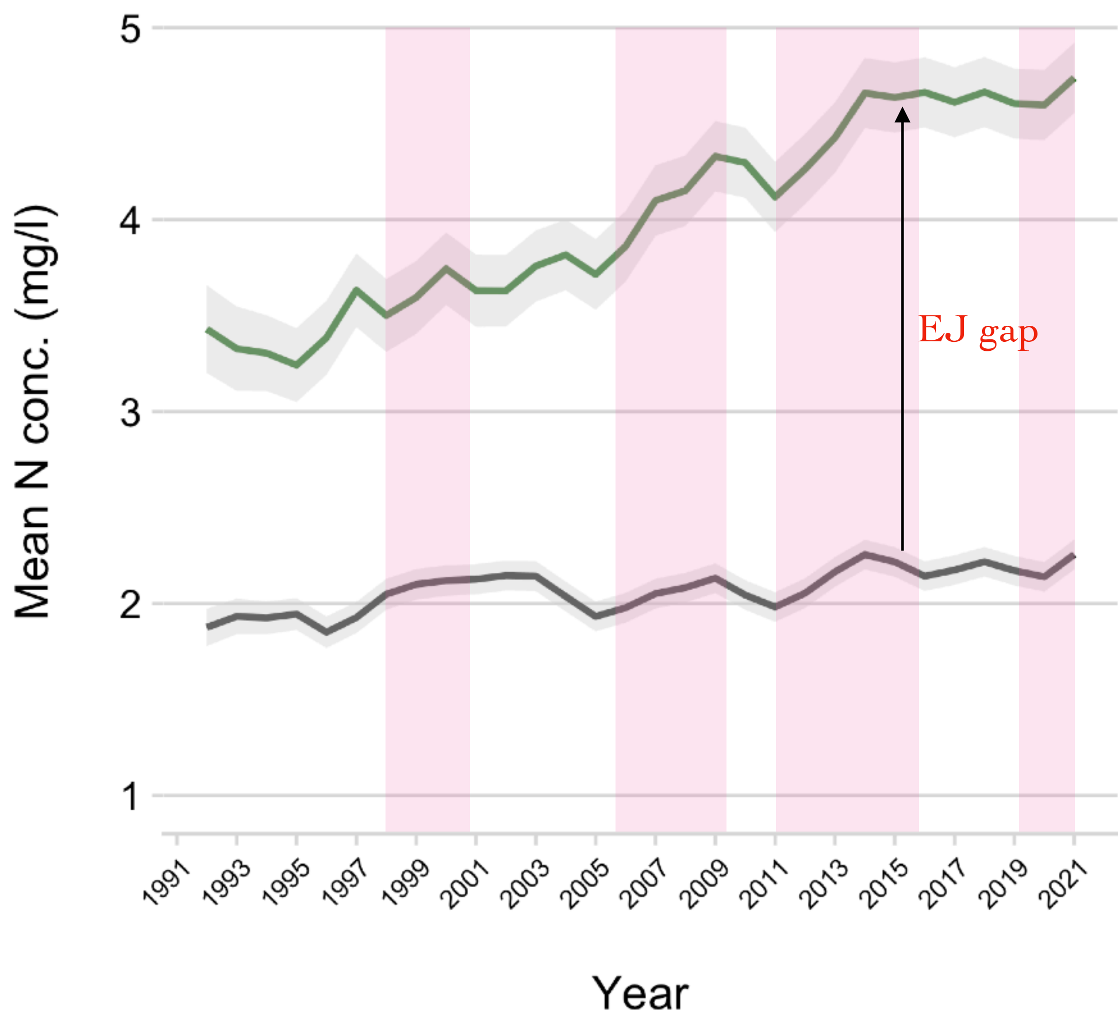

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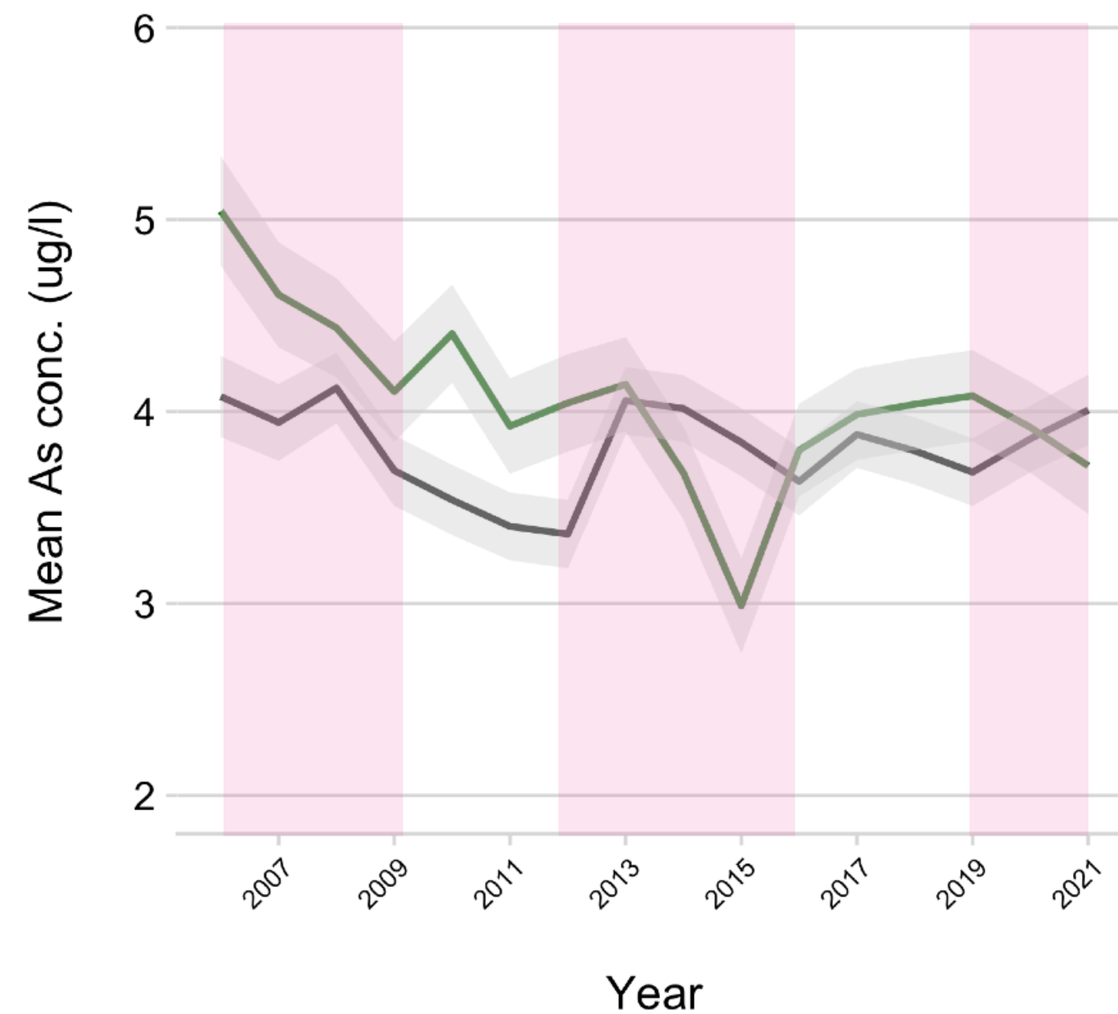


Empirical strategy

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

i = **sample point**

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

w = **water system**

t = **year**

Other baseline econometric specification:

Tables

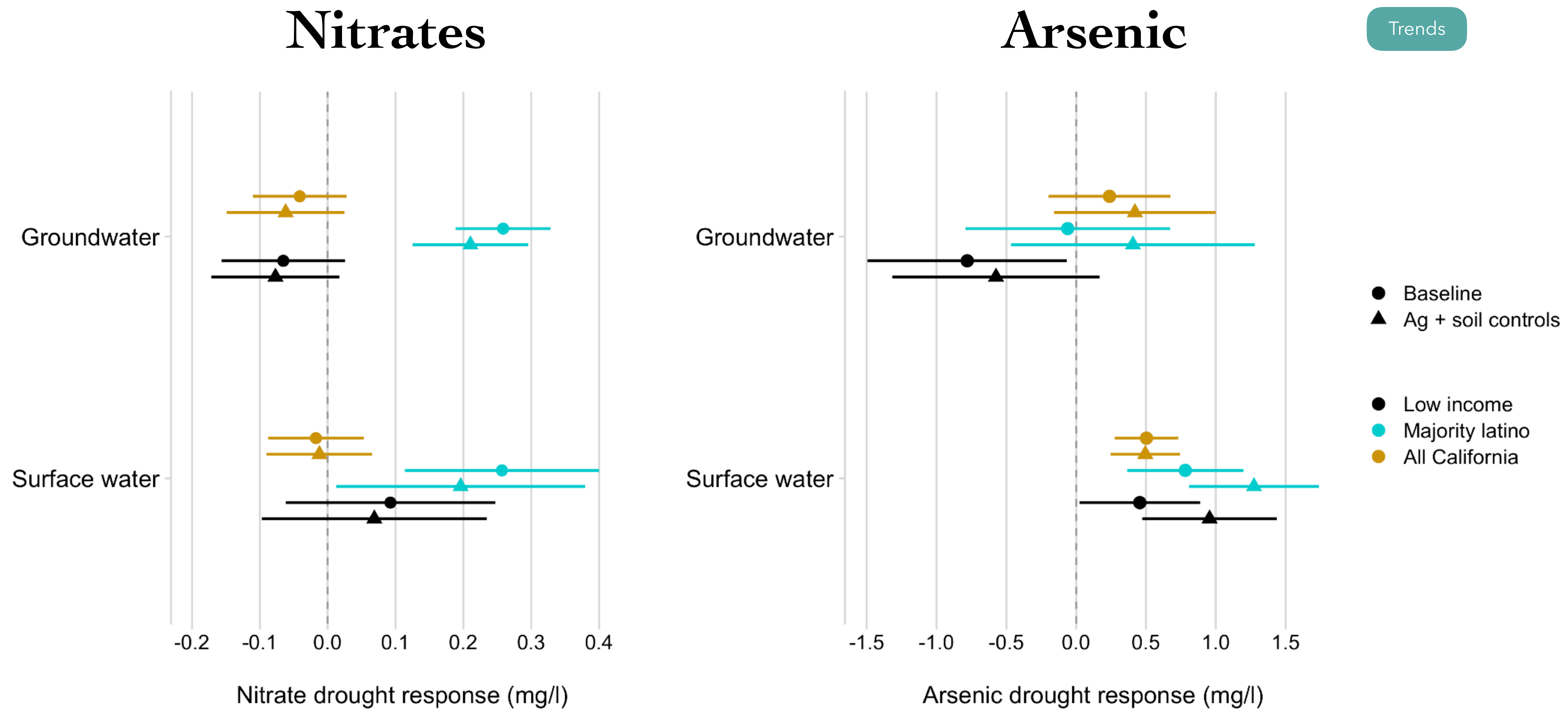
(i) Tested combinations of geographical, administrative units, and year fixed effects.

(ii) Interacted drought with measures of agricultural intensity and soil characteristics.

- # ag wells in 1 mile
- % crop land in 1 mile

Results

Trends



8% of the mean

15% of the mean

Simulating drought effects

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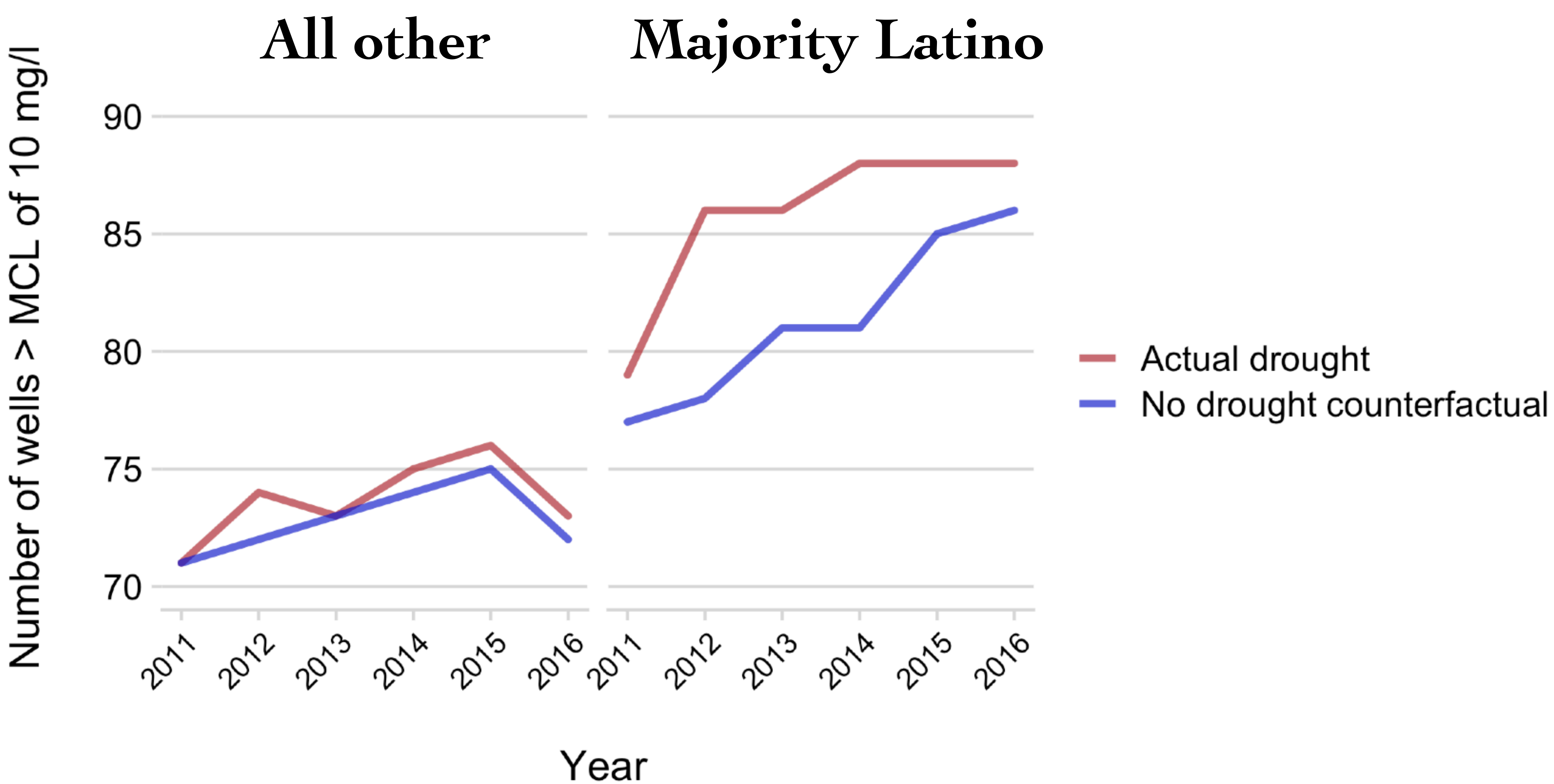

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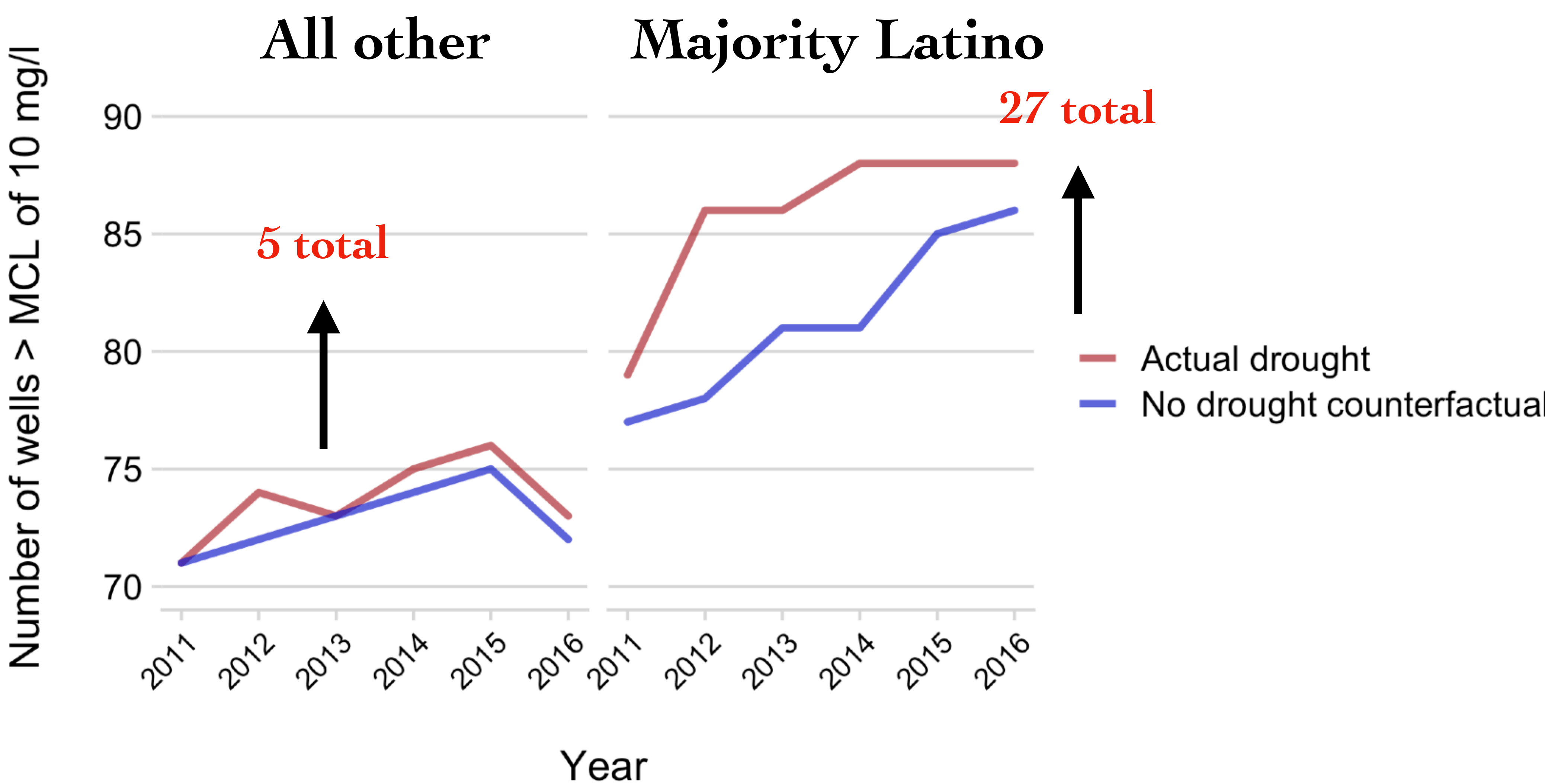

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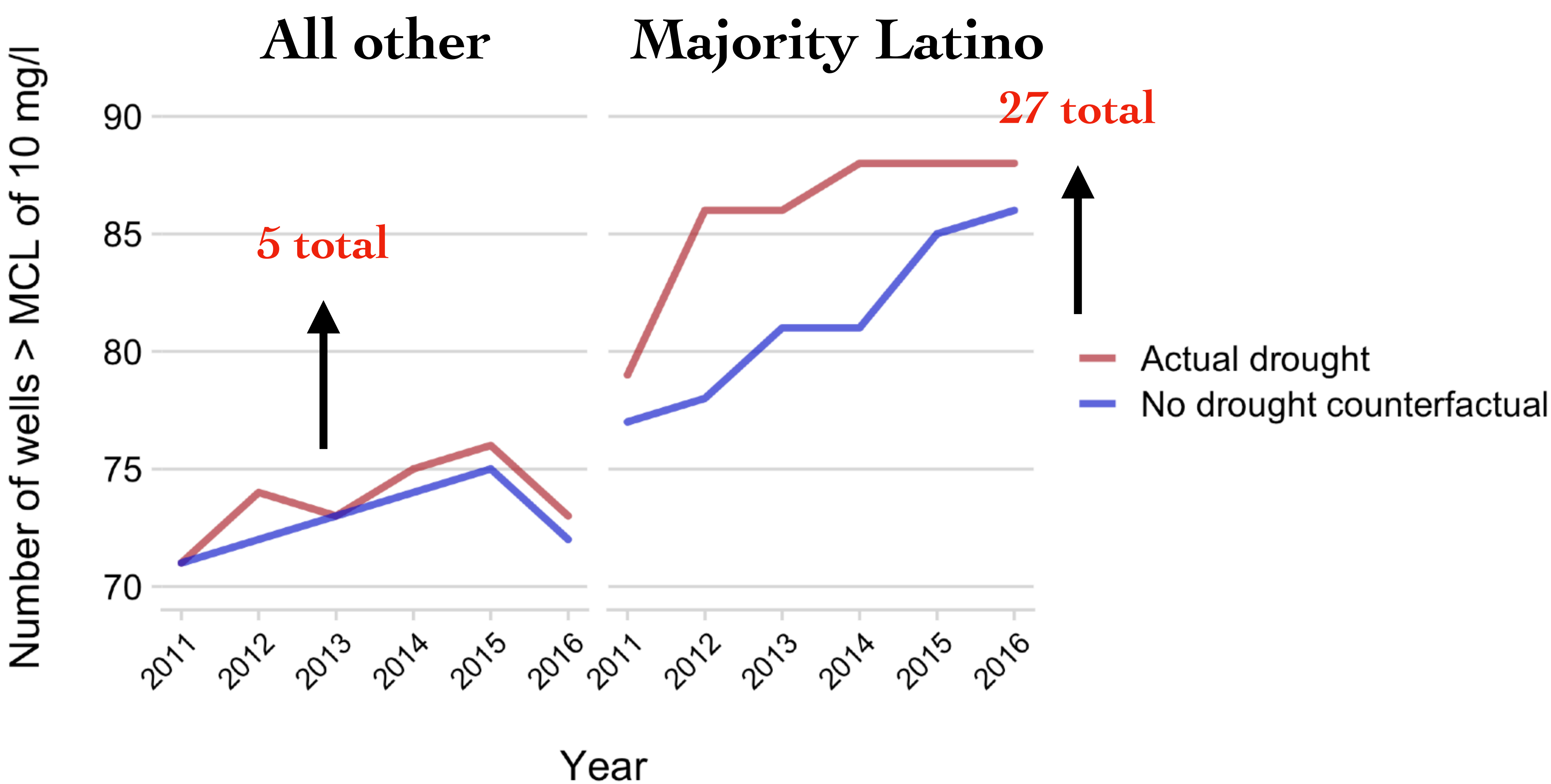

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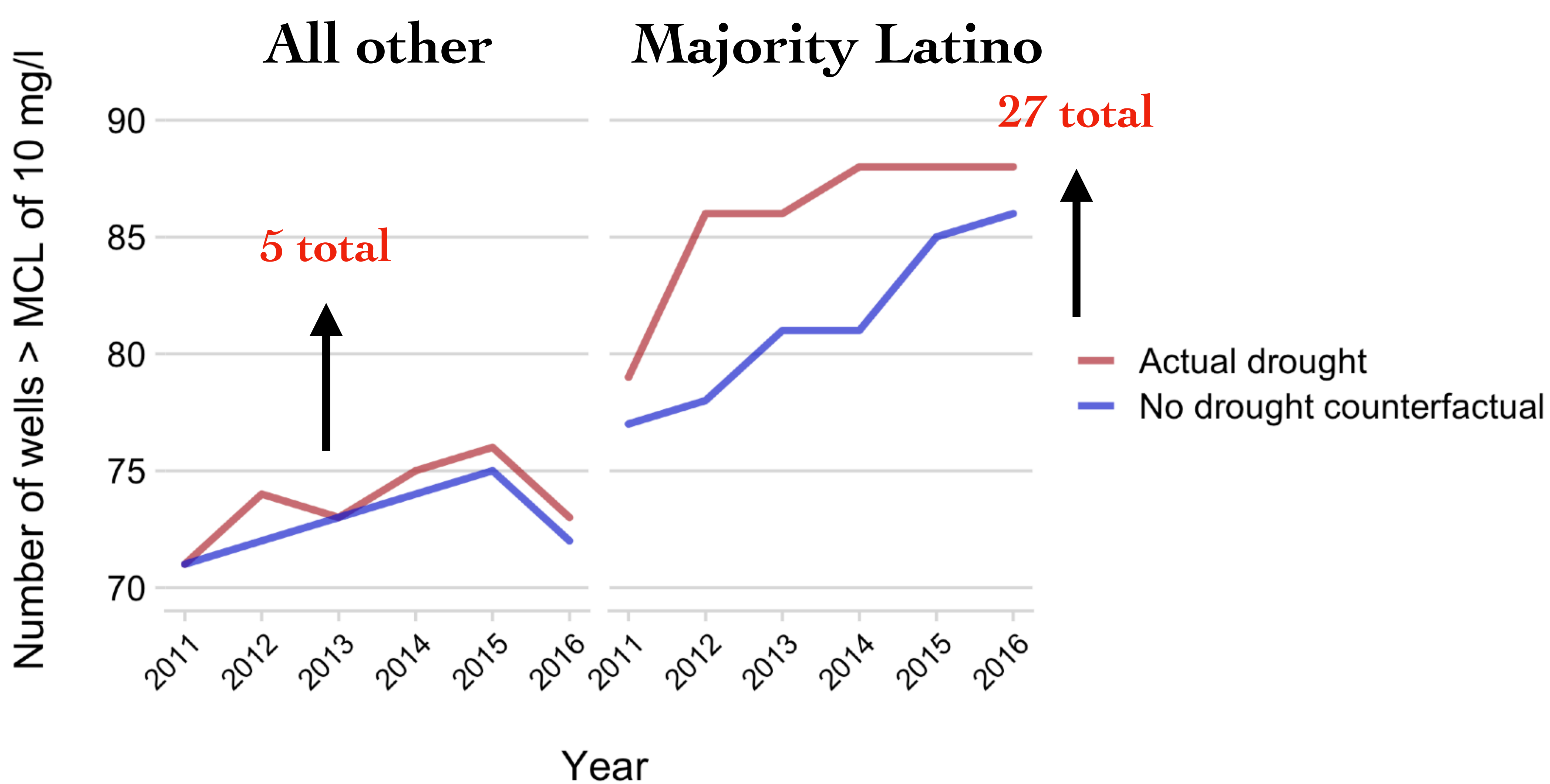

Cost estimation for 2012-2017 drought

- 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	

Exploring mechanisms

Why do we see this distribution even after conditioning on measures of agricultural intensity?

- Agricultural measures are imperfect e.g. historical N applications and AF of water pumped
- Heterogeneous water systems: **sourcing deeper wells** or **investing in water treatment** (imperfectly observed)
  - Safe Drinking Water Act of 1978 and CA's Human Right to Water of 2012 is well intended but more needs to be done
  - Small water systems that serve these minoritized groups lack the **knowledge**, **funding**, and **expertise** to draw up technical plans for application (voluntary)

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State Water Resources Control Board

It Lacks the Urgency Necessary to Ensure That Failing Water Systems Receive Needed Assistance in a Timely Manner

July 26, 2022

- The State Water Board has not prioritized the processing of water systems' funding applications so that the systems can improve their water quality.
  - Over the past five years, the average length of time for water systems to complete their applications and receive funding nearly doubled, from 17 months to 33 months.
  - The State Water Board has not established performance goals or metrics related to its cumbersome application process.

Conclusion

Findings

- Drought can widen existing drinking water quality gap

Next steps

- Dive into mechanisms
  - Target grants
  - Identify vulnerable spots for domestic well users
- Estimate WTP for safe drinking water — detect bottled water purchases?

Policy Implications

- Drought emergency relief not enough
- Policies should account for inequities in drinking water quality
- Targeting by income will not close the gap

Thank you to the attendees and organizers!

Appreciate all comments and feedback:
sandysum@ucsb.edu