Scenarios of Lithium Mining-Community-Aquifer Interactions in Salar de Atacama, Chile: An Agent-based Modeling Approach

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Introduction

The increasing global interest in electric vehicles and low-carbon technologies have been driving the global Lithium production by 20% per year since 2000 with a projection of stronger growth soon. Salar de Atacama in Chile, as the most economically feasible extraction place, become an investment hotspot that attracts global investors rushing into the arena of Li-mining.

Lithium mining process in Salar de Atacama

- Massive water withdrawals
- Pumping rate has increased from 0.1 m^3/s to 1.5 m^3/s
- Concerns on local groundwater depletion, associated impacts on the local ecosystem and social livelihood
- Intensified social conflicts and riots
- Delayed regulatory actions and sustained impacts

- **Research Question**
  How do the Li-mining industry's pumping behaviors affect the groundwater conditions and stress dynamics of local livelihoods, under various mining production projections?

- **Research Objectives**
  Understand how uncertainties in groundwater levels affect community stress and feedbacks
  Understand the critical range of stress thresholds in social systems

Methods

Based on empirical studies about the unique human-aquifer interactions in Salar de Atacama, we used an agent-based modeling (ABM) approach with data from national statistics, company reports, empirical studies, and monitoring sites, and built an ABM of mining-community-aquifer interactions in Salar de Atacama (MCA-SdA, link to model) .

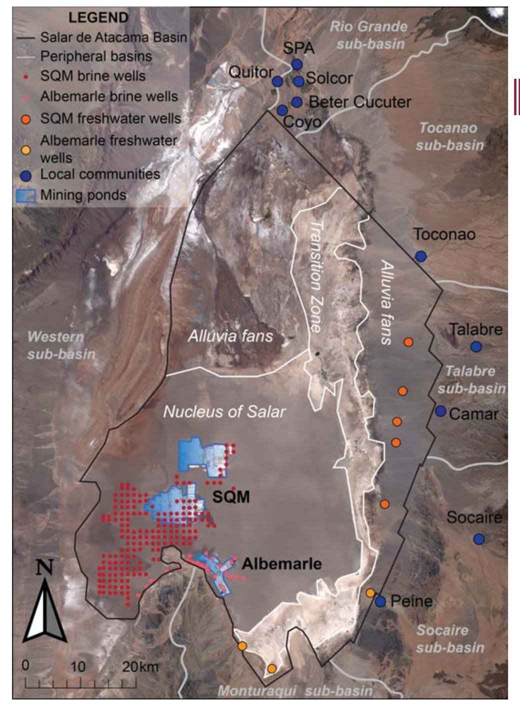


Fig 1. Map of Salar de Atacama

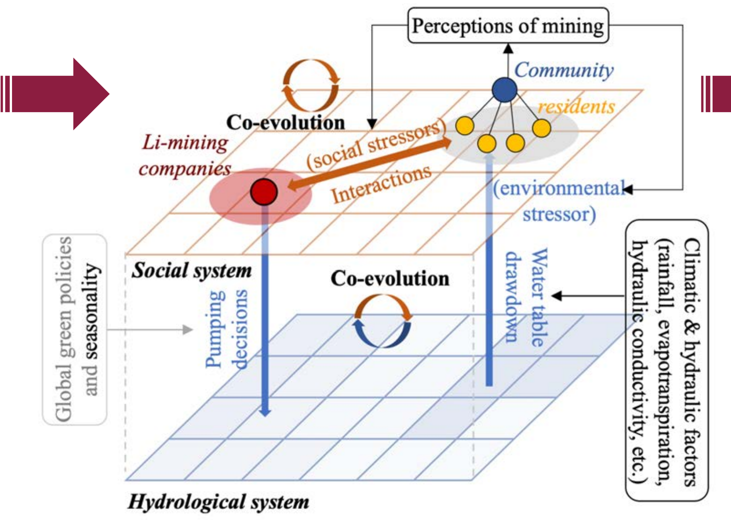


Fig 2. Modeling framework

Three major stressors:
- Drought stress (level of vegetation drying)
- Population stress (labor influx by mining industry)
- Mining stress (scale of mining, proximity to mining)

Stress relief mechanism:
- Financial compensation from mining companies

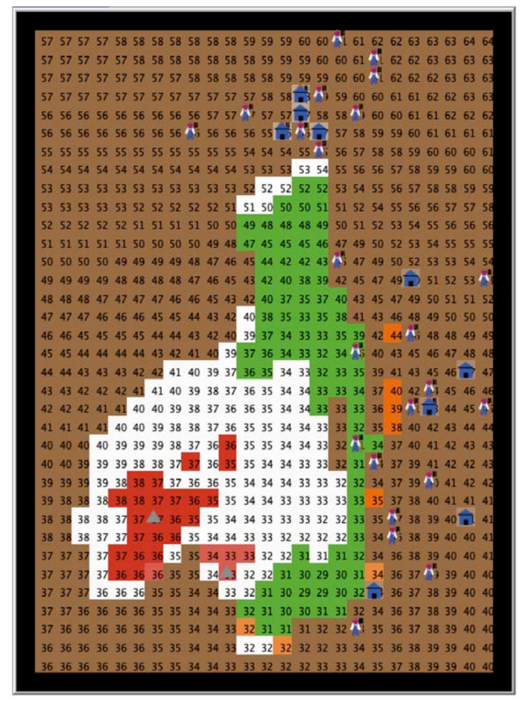


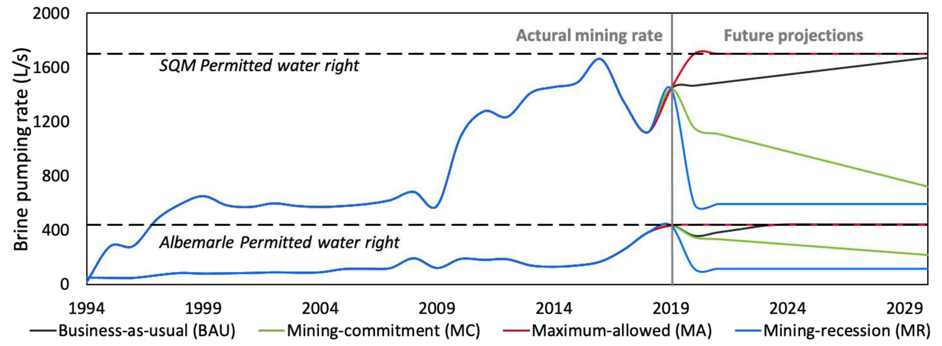
Fig 3. Interface view of MCA-SdA

Results

I Baseline model (1994-2019) and validation

- The simulated drawdowns mostly match the magnitude and pattern reported in other groundwater models about Salar de Atacama.
- The modeled drawdowns accurately reflect the measured level in selected sites, capturing both the oscillations caused by natural processes and the effects of brine pumping.
- The trend and patterns in simulated social stress generally match the actual timeline of mobilization events in the Salar de Atacama.

II Future scenarios (2020-2030)



- ✓ **Business-as-usual (BAU):** *follow the same growth rate*
- ✓ **Mining-commitment (MC):** *strictly follow company's sustainable development plan*
- ✓ **Maximum-allowed (MA):** *rapidly increase to the maximum allowed quota*
- ✓ **Mining-recession (MR):** reduce the pumping rate to the level before they were granted an expansion concession

Simulated groundwater system

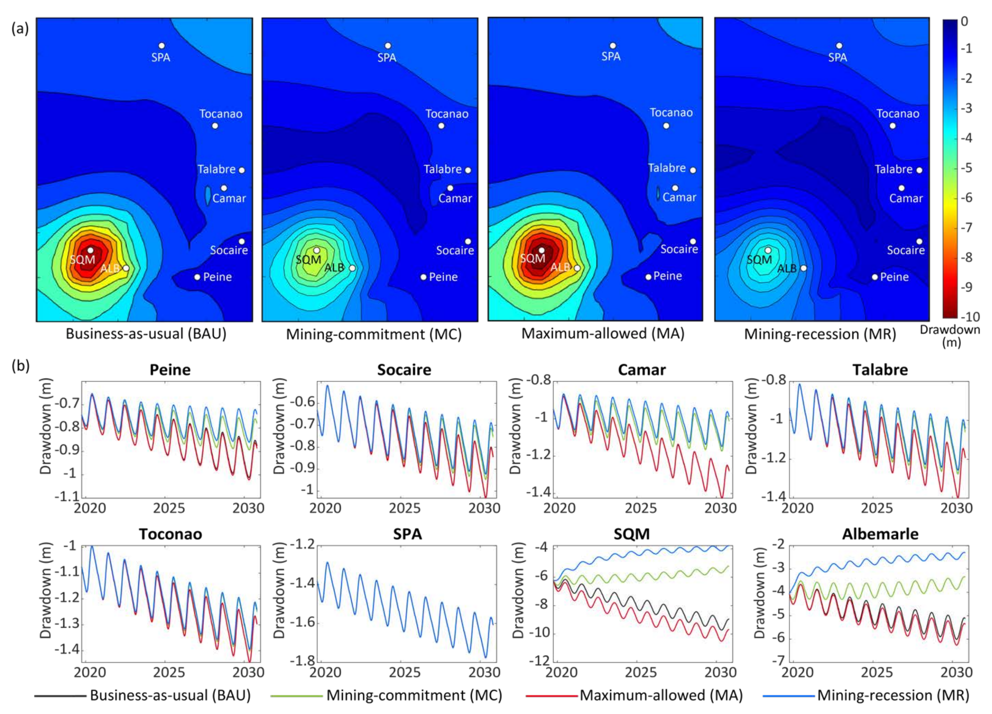


Fig 4. Evolution of groundwater drawdown under four scenarios

Simulated social system

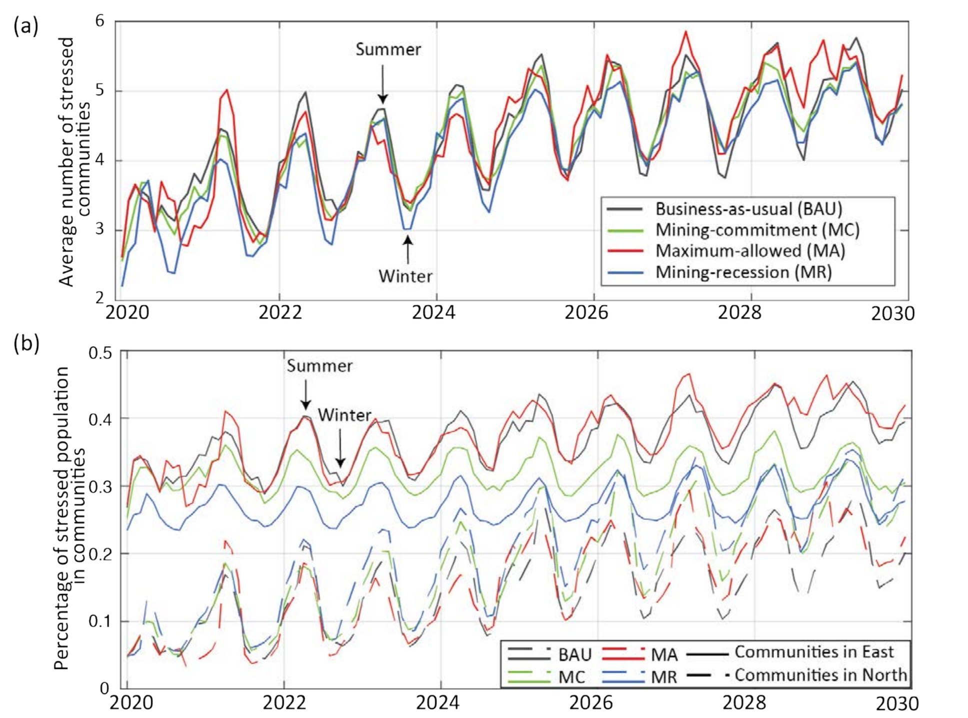
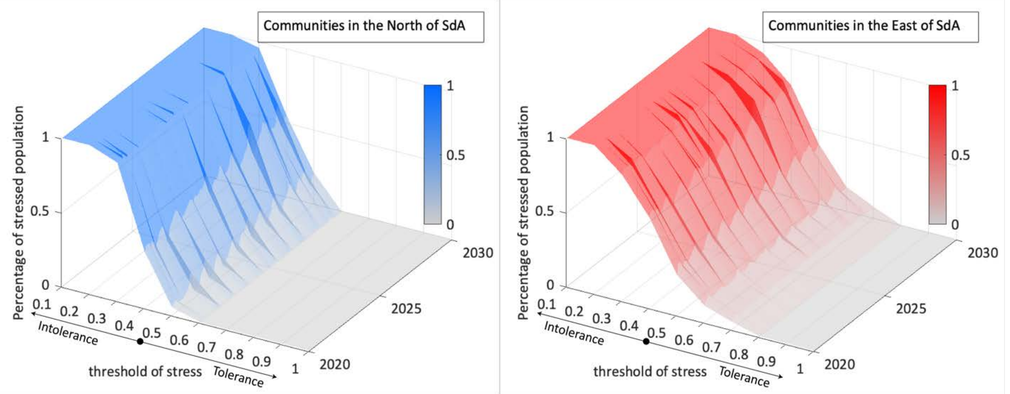


Fig 5. Evolution of simulated social dynamics under four scenarios

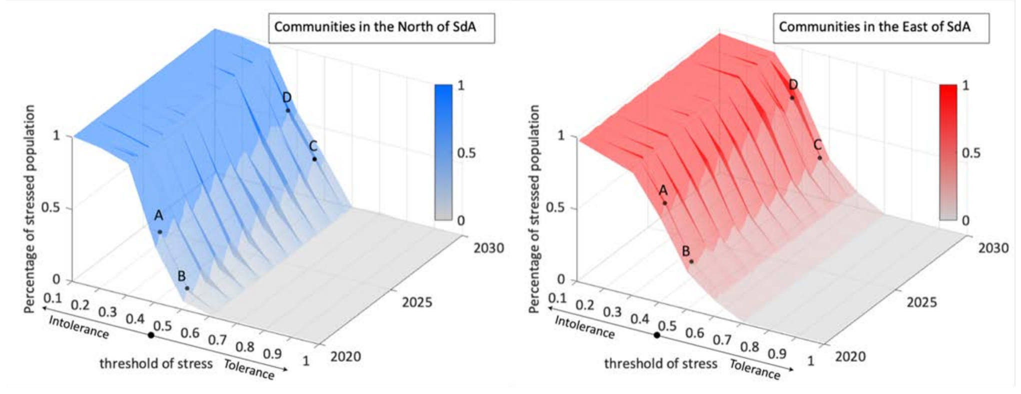
III Stress threshold

Scenarios of expansion in mining water use (BAU & MA)



Eastern residents have diverse mining-related impacts and are more vulnerable to such impacts, especially when extraction (and water pumping) activities are intensive.

Scenarios of reduction in mining water use (MC & MR)



Once mining water use declines, the stressed northern population rises more quickly, and they turn to be more vulnerable and perceive long-lasting impacts once mining largely lessens.

Conclusions

Concerns about the impacts of lithium mining water use have been mounting. This study developed an ABM model to represent the dynamics of Li mining-community-aquifer interactions in SdA. The model evaluates the potential impacts of future mining projections on the aquifer conditions and mining-induced social stress and investigates how such impacts are affected by the uncertainties embodied in groundwater dynamics. Hereby we conclude that:

- ➢ **Adjacent communities are more vulnerable, but the distant ones endure longer impacts**
- ➢ **Lithium mining water use significantly affects local community's wellbeing**
- ➢ **Material uncertainties of groundwater delay feedback, causing mismatched evolution of dynamics in both systems**
- ➢ **A possible striking increase in social stress resulting from the recent social shift towards overburden, underlining the importance of building resilience in regulatory practices.**

Future Works

The results of our model suggest the need and potential for incorporating some pathways in the future that may help increase stress threshold and build community resilience. Some future model improvements may include:

- ➢ Early warning and awareness mechanism
  - *Companies share their projections of impact and potential warning signs with local people, thereby altering the reference point for people's sense of change*
- ➢ Access to timely information on mining impacts
  - Residents are no longer subject to the changes in their location but have a broader understanding of the whole basin.
- ➢ Climate uncertainties
  - Coupling with climate models to understand how climate change contributes to socio-ecological changes.
- ➢ Other important factors require future efforts with other methods or in broader disciplines.
  - e.g., the cultural relations with water; pathways that are not explicitly designed or could not be translated into models