(Un)sustainable mineral mining in South America: Lithium Extraction in Salar de Atacama, Chili

Harry Seijmonsbergen , IBED, FNWI
&
Barbara Hogenboom, CEDLA-ARTES, FGw

UNIVERSITEIT VAN AMSTERDAM

Energy transition through the lens of Sustainable Developments Goals

ENLENS pilot project, 2022-2022:
Mining for energy transition: Understanding drivers of (un)sustainable mineral extraction
Case study: lithium extraction in the Salar de Atacama, Chili
Fieldwork March 2023

Earth Sciences: Dr. Carina Hoorn, Dr. Harry Seijmonsbergen, Paulien Deken & Minnert Wijnands (MES)

Social Sciences and Humanities: Prof. Barbara Hogenboom, Mirko van Pampus MA, Sanne Jansen, Marta Mora, Julian Rocke & Alicia Urios (MIDS)

UNIVERSITEIT VAN AMSTERDAM

Background on Lithium brine environments

- Lithium is present in more than 150 minerals, clays, pegmatites, **brines**, geothermal waters and seawater
- The Central Andes holds the largest known terrestrial lithium resources (~54%) in the Lithium Triangle), mainly in salt plains (Salars)
- The Salar de Atacama (Chili) has extraordinary high levels of Li-concentrations (derived from ignimbrite weathering and high surrounding topography)
- The environment is a balance of four interacting geodiversity components: *geology, geomorphology, soils and hydrology*
- The current climate is hyper-arid, with rainfall <200 mm/yr; the salar is host to unique flora and fauna, fully adapted to the harsh conditions
- The extreme, and unique habitat conditions makes this setting highly vulnerable to (external) disturbances (e.g. brine mining, infrastructure, irrigation, tourism, invasive species etc.)

(Economist, 2017)

The geological and geomorphological environment

Landforms and sources of lithium

- The salar is an intramontane (closed) basin in which (ground)water with dissolved lithium ions accumulates
- Lithium is concentrated because of evaporation, and stored as brines below the salar at depths generally -10m below the surface
- These processes have been active over long time scales >> million years

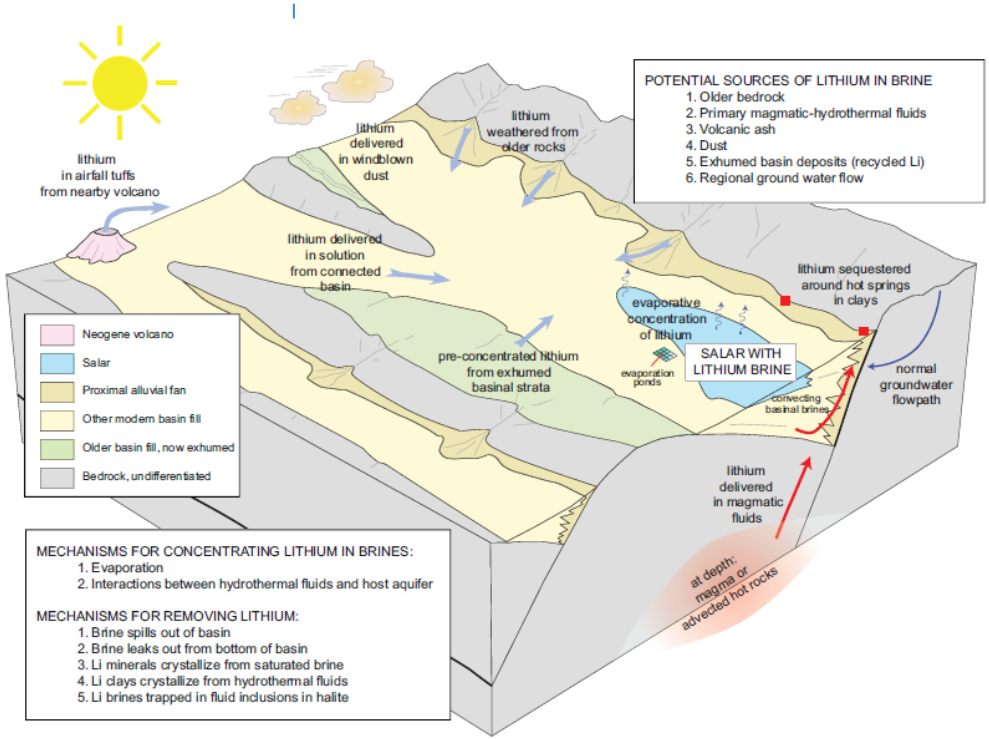
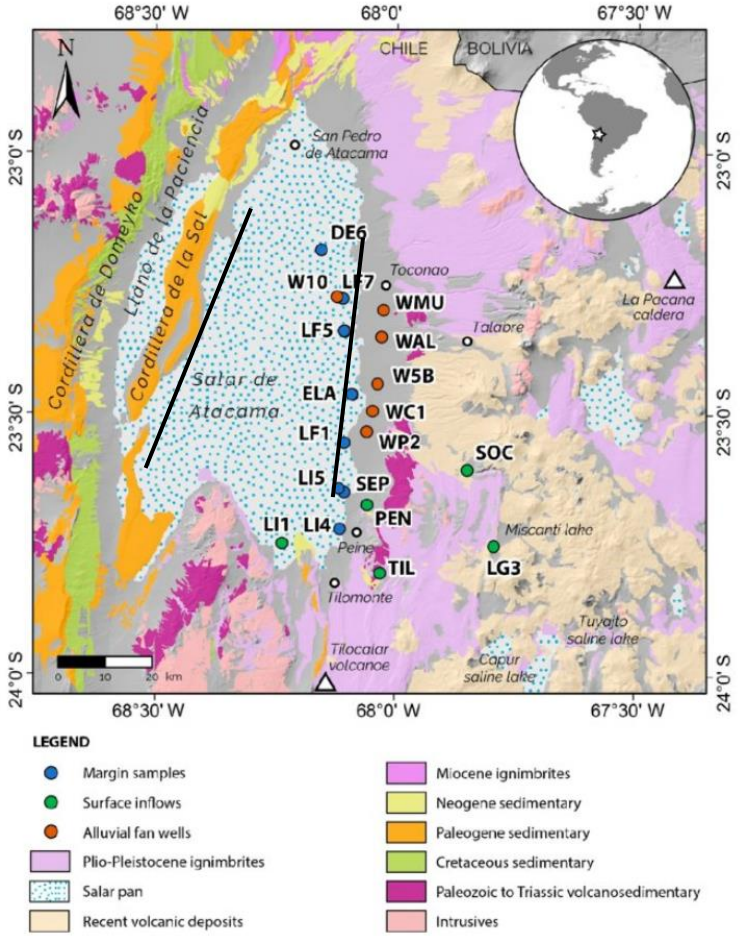


Fig. 2. Summary diagram of the geologic, geochemical, and hydrogeologic features of lithium brines emphasizing the sources, transport, and fate of lithium (adapted from Bradley et al., 2013).

The geological and geomorphological environment

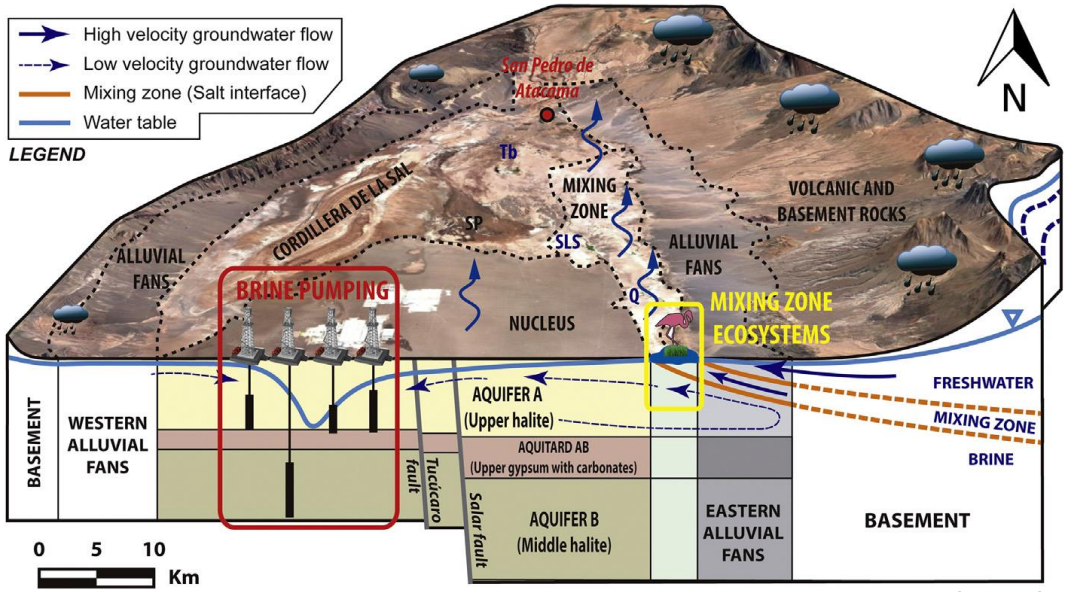
Geological map

- The rock formations reflect a complex history of mountain building, plate collision and volcanic activity
- Subsurface faulting and earthquake activity defines the current position of the salar
- These processes have been active over long time scales >> million years



Hydrology in relation to litium brine mining

- Brine pumping lowers groundwater levels
- Pumping forces less evaporation to occur (damping effect)
- Position of the mixing zone is potentially affected by brine extraction
- Subsurface diversity in sedimentology and fault activity may lead to variation in surface position and water levels of local lakes (lagunas)



Marazuela et al. 2020

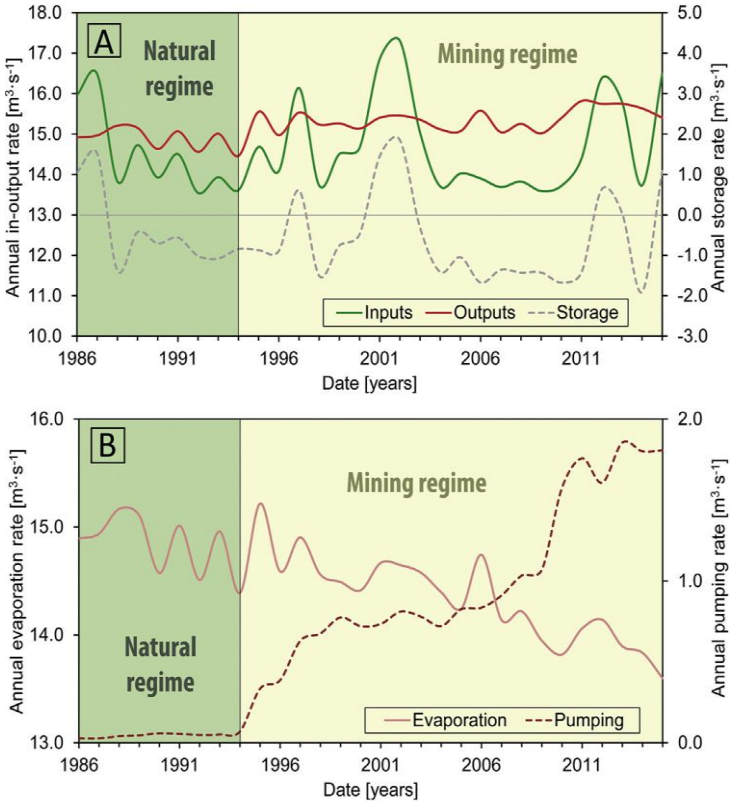
Mixing zone: photo by Paulien Deken

Hydrological changes in the Salar de Atacama

- Availability of water depends on:
  - Input (e.g. rainfall, reinjection)
  - Output (e.g. evaporation, pumping)
  - Storage (groundwater recharge)

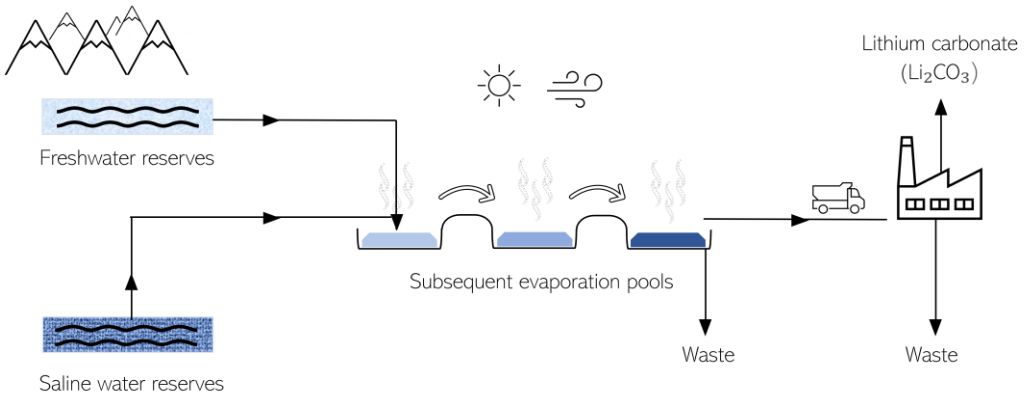
- Damping capacity of the salar
  - Pumping leads to water table lowering
  - Evaporation rate decreases as a result
  - This is defined as *damping capacity* of salt flats

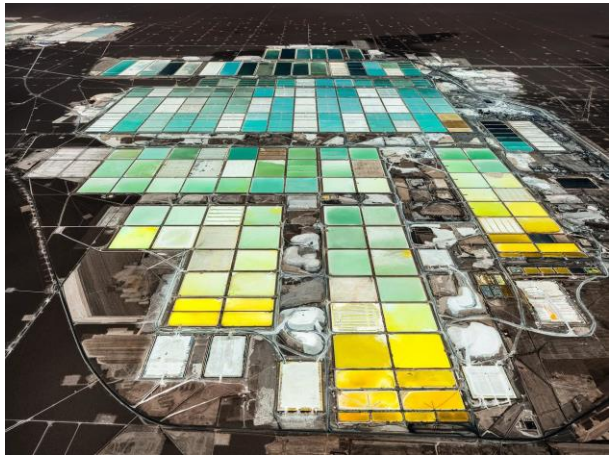
Trends before and after lithium brine mining



Marazuela et al. 2019

Simplified lithium brine mining extraction model





Evaporation pools
https://www.euronews.com/green/2022/02/01/south-america-s-lithium-fields-reveal-the-dark-side-of-our-electric-future

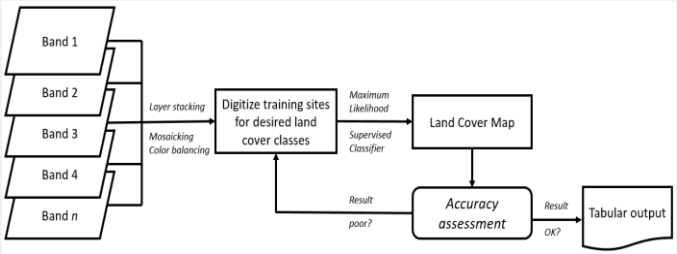
Brine is pumped from beneath the Salar de Atacama. After ~2 years evaporation the resulting mixture is transported to the coastal Antofagasta plant, where lithium carbonate is extracted (adapted from Flexer et al. 2018 and Liu et al. 2019)

https://www.cepal.org/es/eventos/cepal-giz-organizan-seminario-virtual-regimenes-fiscales-litio-paises-triangulo

How to identify and quantify environmental disturbances??

Remote Sensing can assist:

- Land Use and Land Cover changes (before the mining → present-day)



The results are multiple maps and quantified information on increase/decrease over time of mine activity, urban areas, vegetation, salt flats, surface water etc.

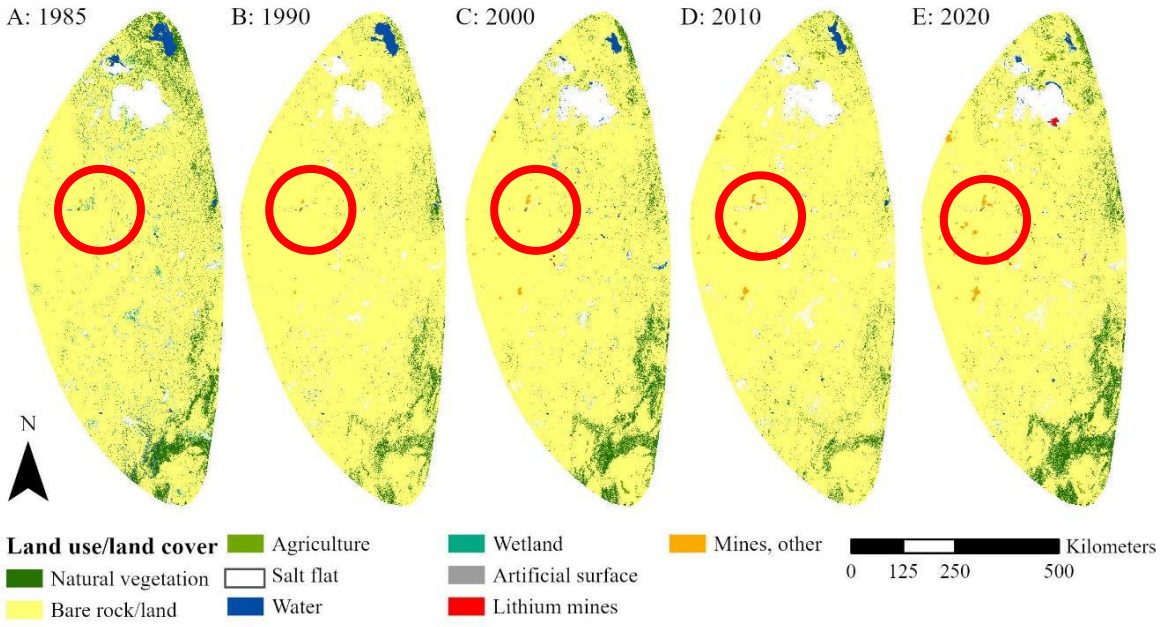
How to identify and quantify environmental disturbances??

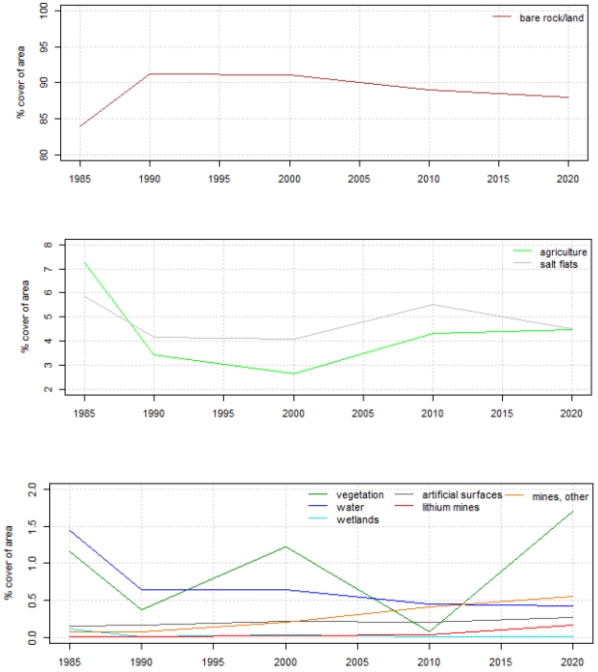
Remote Sensing can assist:

- To detect changes using so-called ratio-based indices, based on spectral signatures

Index	Formula	Function
Normalized Difference Vegetation Index (NDVI) (Escadafal & Huete, 1991)	$\frac{NIR - RED}{NIR + RED}$	Quantifies vegetation
Soil Adjusted Vegetation Index (SAVI) (Huete, 1988)	$\frac{NIR - RED}{NIR + RED + L}(1 + L)$	Quantifies vegetation without soil-induced variations
Modified Normalized Difference Water Index (MNDWI) (Xu, 2007)	$\frac{GREEN - SWIR}{GREEN + SWIR}$	Extract more enhanced water features
Chlorophyll Vegetation Index (CVI) (Vincini et al., 2008)	$NIR\frac{RED}{GREEN^2}$	Leaf chlorophyll concentration
Normalized Difference Salinity Index (NDSI) (Azabdaftari et al., 2016)	$\frac{R - NIR}{r + NIR}$	Detect saline and non-saline soils
Moisture Stress Index (MSI) (Welikhe et al., 2017)	$\frac{MidIR}{NIR}$	Visualizes leaf water content, indicating plant water stress and low soil moisture content
Bare Soil Index (BSI) (Chen et al., 2004)	$\frac{(RED + SWIR) - (NIR + BLUE)}{(RED + SWIR) + (NIR + BLUE}$	Identifying bare land features
Modified Bare Soil Index (MBI) (Nguyen et al., 2021)	$\frac{SWIR1 - SWIR2 - NIR}{SWIR1 + SWIR2 + NIR} + 0.5$	Enhanced bare soil index to distinguish bare soil from built-up area.

Preliminary change results from the lithium triangle 1985 > 2020



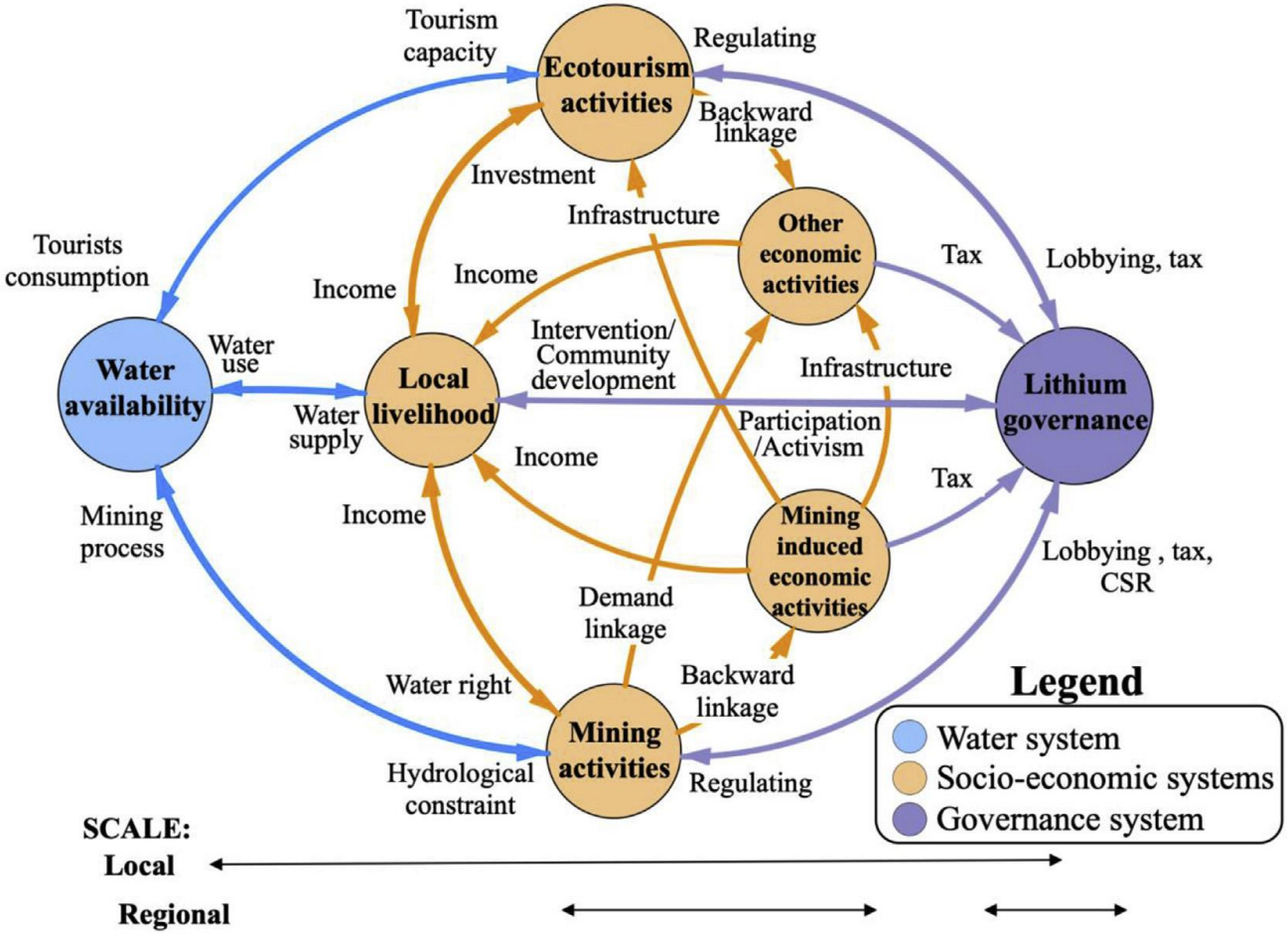


Analyses by A. Verhoek, using Google Earth Engine (unpublished 2022)

Outlook for the Salar de Atacama

- We are in the process of extracting indicators of change for the Salar de Atacama using remote sensing analyses
- This will result in quantitative information on what land use land cover has changed where and when
- Importance: what are the driving factors behind the trends derived from remote sensing analysis?
- For answering that question, on-site research has been conducted by IBED / CEDLA staff and students in order to understand these changes from a multi-disciplinary perspective

Photos: IBED/CEDLA team during visit to Albemarle maining site



Source: Interdependencies of lithium mining and communities sustainability in Salar de Atacama, Chile - Liu, Wenjuan ; Agusdinata, Datu B., *Journal of cleaner production*, 2020, Vol.260, p.120838

Finally mineral wealth, or still ‘open veins’?
(Eduardo Galeano, 1973)

How is societal impact of lithium mining *different* from metal mining: – in San Pedro de Atacama

- No deforestation & pollution – “natural process”
- Less water use – but relatively large
- No displacement of communities
- Limited labour & urbanization – but relatively large
- Innovative arrangements for royalties to local public sector, and especially to local indigenous council

& Little resistance and open conflicts

How is societal impact of lithium mining *similar* to other mining:

- Unknow / uncertain effects on water system – in a desert!
- 'Pressure cooker' of development and change
- Companies very powerful (more than local government) – "absent state"
- Enclave dynamics (with a twist): insiders and outsiders

And…

Conflict and environmental governance

1. Knowledge gaps paralyze debate on impact → directly related to the passive role of the state in lithium governance

2. Companies use their dominant position to depoliticize the conflict → in this way they guarantee continuous extraction

3. Increasing social fragmentation and local tensions

MLAS thesis Mirko van Pampus (2022):
Conflict, Cooperation and Citizenship in Chilean Lithium Mining

Also continuity and change in global context

Global lithium dependencies

- Countries: 1) Australia; 2) Chile; 3) China
- Companies: 1) Albemarle; 2) SQM; 3) Ganfeng; 4) Tianqi

New geopolitics

- US vs China - *America First* and economic decoupling, since 2018
- EU&US vs Russia (&China) – war Ukraine, since 2022
- US vs EU - green protectionism, since 2022

New resource politics – more state control

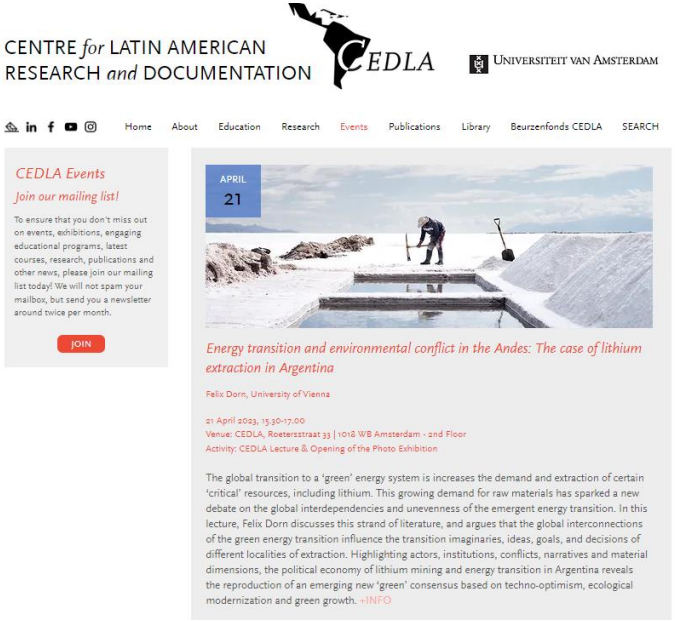
- EU: Proposal for Critical Materials Act (16-3-23) with central purchasing agency
- Chile: National lithium company and new lithium policy

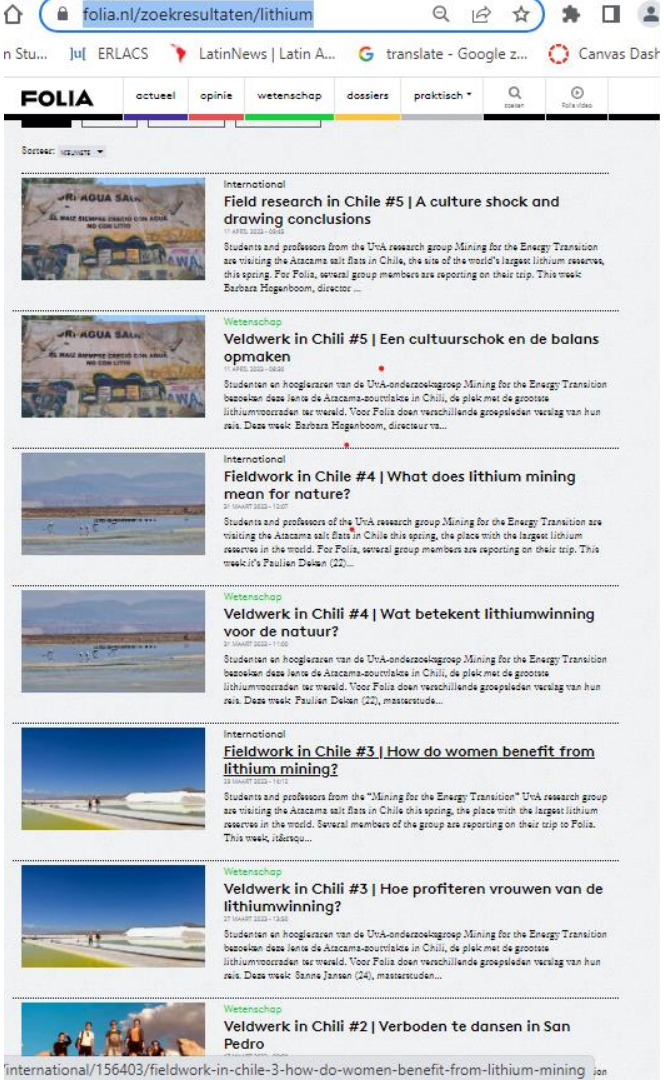
Cycles of globalization (S.G. Bunker, 2003): Successive nations striving to dominate world trade superseding existing capacities to procure and transport over great distance the raw materials they use in great volumes: Portugal, Netherlands, England, US, Japan. + *Now: China…*

Thank you!

A.C.Seijmonsbergen@uva.nl
B.B.Hogenboom@uva.nl & M.C.Hoorn@uva.nl

More on the project and lithium:





Fiebre de litio: multiescalar, multifactorial y multiactoral

↑ Demanda, precios, ingresos + búsqueda de nuevas fuentes y tecnologías

↑ Impactos ambientales, sociales, políticos

↑ Cambios y tensiones políticos, sociales y económicos

↑ Incertidumbres: sobre extracción, gobernanza, cadena de valor, nuevas alianzas

Extracción de litio: viejas y nuevas preguntas

¿Hasta qué punto se reproduce una dependencia tradicional Norte-Sur?

¿Qué significan los cambios geopolíticos actuales para las cadenas de valor globales y la política de materias primas de EE.UU., China y Europa hacia Chile?

¿Y cómo enfrentan las empresas multinacionales, el gobierno chileno y los países consumidores su responsabilidad compartida por una gobernanza (mas) sustentable y justa del litio?

UNIVERSITEIT VAN AMSTERDAM

Relativemente poco conflicto ‘a cielo abierto’ en Salar de Atacama… pero varias coincidencias con casos conflictivos

P.e. Minería de oro en Cajamarca, Peru - Fabiana Li (2015), *Unearthing conflicto. Corporate Mining, Activism, and Expertise*:
Estudios ambientales, programas de monitoreo de agua, parámetros técnicos y evaluaciones de riesgo => una <u>cientificación del conflicto</u>

- Régimen de autorregulación: la empresa realiza EIA para la aprobación del proyecto
  - Hacer mapeos
  - Identificar impactos que son técnicamente manejables
  - Realizar “Manejo del agua” (no: “consumo”)
- <u>Tecnificación de problemas; más información, pero no más confianza</u>
- Grupos de la sociedad civil obligados a responder con estudios y contraargumentos científicos, o no participación

Conflicto y Gobernanza Ambiental

1. Interacciones colaborativas y conflictivas entre diferentes partes involucradas
    - El estado
    - Las dos empresas de litio
    - Las comunidades alrededor del Salar

2. Cómo estas están formadas por las estructuras económicas neoliberales chilenas?

- Gobernanza de litio de restringida → liberalizada
- Cadena de producción en manos privadas
- Control público limitado

Conflicto y Gobernanza Ambiental

3. El papel pasivo del estado permite un modelo de gobernanza más híbrido → más agencia para las empresas y las comunidades

4. Este modelo de gobernanza empresa-comunidad oscurece importantes contradicciones, crea un falso sentido de intereses compartidos y prioriza la autorregulación sobre control formal

5. Comunidades que saben negociar con las empresas disfrutan de un empoderamiento y apoyo financiero sin precedentes

6. Lo que aquí se negocia es una compensación temporal y condicional → un empoderamiento del consumo, no de capacidad civil o política

MUCHAS GRACIAS

- **Centro de Estudios y Documentación Latinoamericanión: www.cedla.nl**
- Libro *Gobernanza ambiental en América Latina* (2015): https://www.clacso.org.ar/libreria-latinoamericana/buscar_libro_detalle.php?id_libro=941
- Tres reportes sobre las nuevas relaciones actuales de América Latina y el Caribe con China (2022): https://www.cedla.nl/china-lac

- **ENLENS**: https://www.uva.nl/en/shared-content/zwaartepunten/en/energy-transition-through-the-lens-of-sustainable-developments-goals/enlens.html
- https://www.folia.nl/international/156132/field-research-in-chile-1-on-to-the-northern-mining-town-of-calama
- https://www.folia.nl/international/156202/field-research-in-chile-2-forbidden-to-dance-in-san-pedro