**Title**
The Role of the State and The Environmental Impacts of Lithium Mining in Jujuy, Argentina



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**Publication Date**
2021

Peer reviewed|Thesis/dissertation

UNIVERSITY OF CALIFORNIA

Los Angeles

# The Role of the State and The Environmental Impacts of Lithium Mining in Jujuy, Argentina

A thesis submitted in partial satisfaction

of the requirements for the degree Master of Arts

in Geography

by

Emily Michelle Ortiz

2021

ABSTRACT OF THE THESIS

The Role of the State and the

Environmental Impacts of Lithium Mining in

Jujuy, Argentina

by

Emily Michelle Ortiz

Master of Arts in Geography

University of California, Los Angeles, 2021

Professor Kelly Ann Kay, Co-Chair

Professor Stephen Andrew Bell, Co-Chair

In the last decade, the demand for lithium has skyrocketed after it was discovered that it was efficient for making batteries. Lithium's tremendous growth forecast going forward is characterized by the coming together of energy, automotive, and technology industries to foster the future of renewable energy. While this global commodity market may present the opportunity for a sustainable future, the extraction of lithium is unsustainable in the local context. The teleconnections framework provides a lens to understand how political and economic processes—spatially distant to the site of extraction—accelerate biophysical changes at the local scale. This thesis examines the role of the provincial government as an actor and stakeholder in lithium mining projects and the extent to which this translates to land use changes in Jujuy, Argentina. I approach the role of Jujuy's provincial government as modeling the neo-extractivist logic of development. Based on a review of relevant national and provincial legal and political frameworks, I explore the various ways in which the state—as a governing authority and stakeholder—justifies the intensification and exploitation of lithium mining as a model of development. I suggest that Jujuy's provincial government is motivated by the short-term socio-economic benefits of lithium mining, but it is at the expense of long-term environmental damage. Next, using publicly available, high resolution satellite imagery from Google Earth Pro, I quantify the biophysical changes of neo-extractivism in Jujuy over a four-year period—from 2016 to 2020. I focus on the Sales de Jujuy lithium mining project in Jujuy to identify the change in land use for mining operations. The area change in surface mining operations illustrates that land use can undergo large area transformations reflective of shifting political and economic conditions at varying scales. By addressing both the human and environmental dimensions of lithium mining in Jujuy, this thesis calls attention to the global market conditions and organization of Argentina's lithium mining sector (through its policies and governance structures), which give rise to the environmental problems directly impacting the local scale.

The thesis of Emily Michelle Ortiz is approved.

Gregory Stewart Okin

Kelly Ann Kay, Committee Co-Chair

Stephen Andrew Bell, Committee Co-Chair

University of California, Los Angeles

2021

DEDICATION

To my mom and dad for their unconditional love

and support in the pursuit of this degree.

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ACKNOWLEDGEMENTS

I would first and foremost like to thank Dr. Stephen Bell and Dr. Kelly Kay for believing in me and for their unconditional support in my journey as a Geography Departmental Scholar. Without the guidance and advice of Stephen and Kelly, this geographical research would not have been possible.

I am thankful for my committee member, Dr. Gregory Okin, for his valuable insights on the remote sensing section of this research. I also extend my appreciation to Dr. Chelsea Robinson and Francisco Ochoa, for their time and sharing their suggestions for improving my remote sensing methods and writing.

My heartfelt gratitude goes to my family and friends for their love, encouragement, and support during the completion of this degree. To Cole Andrews, for his patience and care when I needed it the most. To my parents, for constantly inspiring me to pursue my goals. Finally, to the many more people whose names I did not mention, I am incredibly grateful for all the support I received throughout this process.

## INTRODUCTION

A global focus on sustainability has called for the reduction of anthropogenic carbon emissions to mitigate the effects of climate change. In particular, the challenge of a "zero emissions future" has largely been directed towards the transportation industry. As one of their contributions toward this green endeavor, many automobile companies (e.g., Tesla, Toyota, Mitsubishi, etc.), since 2008, have been expanding their production and sale of electric vehicles (EV), hybrid (HEV), and plug-in hybrid vehicles (PHEV). Electric mobility has also been promoted by many countries, such as the United States, in their pledge to foster a green energy future.[1] The increasing popularity of electric vehicles has stimulated demand for lithium because it is the main source material in electric car batteries. Lithium-ion batteries (LIB) are also used in other popular electronics, such as cell phones, tablets, and laptops. Since the commercial release of the LIB in 1991, the batteries' high-power density, energy storage capacity, technological diversity, prolonged life cycle, low maintenance cost, and its utility as a viable means of storing renewable energy, has helped it become a prominent technology (Narins, 2017; Zubi et al., 2018; Zeng et al., 2019; Wen et al., 2020). Lithium-ion batteries marked a major milestone in the transition to renewable energy sources and in the electric vehicle market. Following the 2016 Paris Deal, where 195 countries outlined a plan to keep the increase of global temperature rise under 2 °C, the demand for energy storage (lithium-ion) batteries grew 60% (Al Jareeza, 2019). This demand is expected to grow; as one example, Tabelin et al. (2021) forecast around a 20-25% growth in the lithium supply by 2025 because of recent policies (by countries, states, and cities) promoting the switch to electric vehicles (to abandon gasoline-powered vehicles) and the substantial increase in global electric vehicle production.

[1] For example, see President Biden's Green New Deal targeting clean energy and electric vehicles in Phillips (2021).

Over half of the world's lithium deposits lie in brines underneath the salt flats in the deserts of Chile, Bolivia, and Argentina. These countries make up what has popularly been referred to as "The Lithium Triangle." Of the three countries, only Chile and Argentina have commercially operating lithium mining projects, though Bolivia has future projects underway. According to 2020 statistics, 19.3 million tons of lithium resources have been identified in Argentina, along with 1.9 million metric tons in proven reserves, making the country one of the world's top producers of lithium (Gonzalez, 2021). Although the lithium mining industry has proliferated in these three countries, the extraction of a non-renewable resource such as lithium has also had damaging local social and ecological effects.

Chile, Bolivia, and Argentina are characterized as resource-rich and fall into the classic patterns of Latin American dependency, which links the cause of underdevelopment in these countries to foreign and domestic political and economic factors (Dietz, 1980; Cardoso & Faletto, 1979). All three countries share a history of colonization, exploitation, and extractive economies. In an attempt to use lithium mining to overcome these histories in pursuit of social and economic development, these countries have taken similar yet distinct trajectories. However, specific institutional, technological, political, and environmental conditions have complicated these efforts towards economic and social progress (Bridge, 2017). As discussed by Bebbington et al. (2008), the expansion of mineral frontiers continues to drive new forms of social conflicts—primarily related to poor governance and the environmental pressures created by extractive activity. In the case of lithium, the environmental conflicts raised by communities living near the mining areas complicate the notion of "progress" because of the disregard for the health and rights of local [frontline] communities (Anlauf, 2015).

Argentina has a history of being an export-based economy (mainly of primary agricultural products), but in contrast to Chile and Bolivia, the country has a less established history of large-scale mining. The increase in lithium mining projects in Argentina is coupled with the global demand for lithium in recent years and both national and sub-national (provincial) natural resource/mining policy trends. Argentina's development trajectory through promoting the growth of its lithium mining sector has been through creating favorable conditions to attract foreign investment to finance large mining projects. Although Argentina's lithium mining industry is monopolized by transnational corporations, the Argentine province of Jujuy has taken an interest in being directly involved in the management of its lithium reserves and developing the resource potential for the province.

However, the extraction of lithium is quite unsustainable at the site of the mines in Argentina. This is because of the biophysical composition and conditions of the salt flats where the lithium mines are located. The reconfiguration of the salt flats for lithium extractive activity has resulted in the environmental degradation of the local biophysical systems. More specifically, the strain on the already scarce water resources in the salt flats has become the biggest area of contention for local communities living near the lithium mining operations. Although extracting lithium from the ground is a relatively effective and cheap process, it requires about 500,000 gallons of water per metric ton of lithium (2020). In Jujuy, local communities have raised concerns about the effects of lithium mining on their local aquatic systems, as the mining is affecting both water quality and quantity in this arid region.

This thesis is organized around two central themes: the role of the state and the environmental impacts of lithium mining. In Argentina, the subsoil belongs to the provincial governments. By contrast, Chile and Bolivia's federal governments are largely in control of their country's lithium reserves; therefore, the extraction and commercialization of lithium are dictated by national policies (Voskoboynik & Andreucci, 2021). In this research, "the state" refers to the provincial government. Jujuy's provincial government's direct involvement in lithium mining projects to promote socio-economic development models the neo-extractivist logic of development (Gudynas, 2011). Contrary to the traditional extractivist model which adopts neoliberal policies to support the extraction and exportation of mineral reserves primarily facilitated by transnational corporations, neo-extractivism refers to a more active role of the state to regulate the economic flows of their resources to secure financial incentives to support their own development agendas. While this may improve economic conditions for the peoples of countries that pursue neo-extractivist policies, the extraction of natural resources inevitably results in environmental damage.

Based on a review of primary and secondary literature in English and Spanish and a review of relevant laws and statutes, the first half of this work addresses the role of the state in Argentina in current and future lithium mining. Through an analysis of the Olaroz Lithium Project, better known as the Sales de Jujuy project in Jujuy, Argentina, I explore the governance structures and legal frameworks in Jujuy that give precedence to neo-extractivism as a mode of development. Since national and provincial laws and institutions act as the legitimizing force of mining operations and play a role in dictating human-environment relations, I examine the ways the state promotes the development of its lithium mining industry. Jujuy's provincial government's participation in lithium mining projects is incentivized by the benefits projects can generate. To complicate this, I point out the unequal costs and benefits that exist among the stakeholders of lithium mining in Jujuy. Finally, I discuss the tensions between Jujuy's provincial government's desire to exert control over its lithium reserves and its desire to develop the lithium market's potential through large-scale mining projects which still depend on foreign investment.

The second half of this work utilizes satellite imagery to identify how neo-extractivist projects translate to environmental changes on the ground. My GIS and remote sensing analysis are motivated in part, by the teleconnections framework (Friis & Nielsen, 2017), which views land use change patterns (over time) as an indicator of political and economic processes operating at varying scales. Following from this, the reconfiguration of land use in the Argentine salt flats to support large-scale lithium mining projects is reflective of changes and processes in political and economic structures in locations spatially distant to the site of extraction. Thus, the ecological impacts of lithium mining cannot be solely attributed to lithium extraction methods at the local scale. The distant flows and processes occurring at varying scales, including international carbon reduction targets and national policies for vehicle electrification in many Western nations, accelerate the expansion of lithium mining operations and are essential to acknowledge in the assessment of the environmental impacts of lithium mining in Jujuy. From a teleconnections perspective, I show how human processes interface with biophysical (land change) processes. In this thesis, I accomplish this by quantifying the extent of mining impacts in Jujuy.

The thesis begins by situating the geographical context and providing a broad overview of Argentina's development trajectory to its present state. This includes lithium mining in Argentina. Secondly, I draw upon the literature which outlines the historical and contemporary academic debates surrounding natural resources, mining, and development in Latin America (broadly) since the 1960s. By tracing a genealogy of these debates, we can better understand this current moment of neo-extractivism in the case of lithium mining in Jujuy, Argentina. Next, I discuss the legal frameworks and changes in political conditions in Argentina and Jujuy that suggest the pursuit of lithium mining under the banner of national development is not without complications. Lastly, I quantify the spatial extent of lithium mining using the Sales de Jujuy lithium mining project in Jujuy as a case study. It is my hope that by bridging both the human and environmental dimensions of lithium mining in Jujuy, I can draw attention to the wide-ranging impacts of extraction—from the hyper-localized ecological impacts to the global political and economic drivers for expanded mining—just as electric batteries are posited as a global "solution."

**BACKGROUND**

Argentina's history of uneven development, political turmoil, financial instability, and sovereign debt has continued to plague the country since its colonization. The country's abundance of resources allowed it to flourish and ascend economically following Spanish settlement. This section begins by outlining a brief history of Argentina's development trajectory, from its declaration as a republic to the present. Argentina's development of its lithium mining sector is an attempt for the country to turn over a new chapter in its endeavor to regain financial stability, control over its resource wealth, and to contribute to the global energy transition. In consideration of this, a discussion of lithium extractive methods is placed in conversation with the environmental implications associated with this extractive activity. Finally, I introduce the Sales de Jujuy case study to demonstrate the interplay of social, political, and economic processes in the development of lithium mining operations in Jujuy.

### *Argentina's Geographical Configuration and Natural Resources*

Argentina covers most of the southern cone of the South American continent (see Figure 1). The country shares a border with five other South American countries and the South Atlantic Ocean along its eastern coast. Argentina's federal republic is comprised of twenty-four administrative divisions: twenty-three provinces and one autonomous city, Buenos Aires Capital Federal (see Figure 2 for reference). The country's varied geographical specializations highlight its abundance of natural resources. For example, the northwest of the country is home to the Andes mountains and is rich in mineral deposits such as silver, tin, iron, and lithium (to name a few). To the east of the Andes, in the interior of Argentina, lies the flat fertile grasslands known as the *Pampas*. This area is the agricultural hotspot of Argentina and has been the country's main economic engine for decades. The Pampa's main crops include soybeans, wheat, maize, sunflower seeds, and grapes, along with livestock such as cattle and chicken. Argentina is currently the world's third largest exporter of soybeans (Grijalba et al., 2021). The country also possesses the fourth largest reserve of shale oil and second largest reserve of shale gas (Primera et al., 2019). These major deposits of shale oil and shale gas are located to the south of the *Pampas* in the northern Patagonia region, commonly referred to as *Vaca Muerta*. In highlighting Argentina's geographic specializations and natural resources, the aim is to illustrate the fact that the country has had ample resources at its disposal, yet many parts of the country where these resources are found (except for Buenos Aires) have faced staggering development trajectories.

### *A Brief History*

The Constitution of 1853 declared Argentina a republic. This established Argentina's civil law legal system. Under a civil law system, the ownership of the subsoil minerals is always in the state, exclusive, inalienable, and imprescriptible (Orihuela, 1996).[2] This ownership of natural resources by the federal government persisted until 1994. Since 1853, Argentina had experienced steady economic growth (Spruk, 2019). It led an export-oriented growth continuing with its existing livestock industry. During 1875-1879, Argentina's exports were mainly hides, wool, and salted meat (Diaz-Alejandro, 1982). Towards the end of the century and at the turn of the century, the country's main exports diversified to agricultural products such as wheat and corn. The beginning of the 20th century in Argentina is characterized by processes of industrialization, which was aided by the influx of European immigrants, consisting mainly of Spanish, Italians, and Germans. This further reinforced a European class structure that was part of the country's longer settler colonial history.

A Peronist Constitution later replaced the Constitution of 1853 under the country's rule of General Juan Domingo Perón (served as President of Argentina from 1946-52, 1952-55, 1973-74). Perón's new Constitution emphasized social rights along with the social function of property. Under a regulatory framework that Perón and his popular wife, Eva Perón, promoted, price and rent controls were implemented that undermined property rights and increased transaction costs (Spruk, 2019). This period of widened government control through a series of nationalizations led to the dismantling of the rule of law in Argentina (due to debt, unconstitutional actions, inflation, etc.), leading to Perón to be overthrown by a military and civilian uprising in 1955 (Spruk, 2019). Violence, military coups, political unrest, institutional

[2] In the civil law countries of Latin America (from Mexico to Argentina), the state is the legal owner of all continental and maritime underground land within their territorial limits (Orihuela, 1996). Therefore, foreign/private interests in minerals must be granted a mining concession by the state, which allows a non-state entity to explore and exploit mineral resources.

breakdowns, and human rights violations plagued Argentina in the years after Perón was overthrown. The instability of the Argentine government in the second half of the 20th century led to the country's rapid economic decline and weakened its ability to develop (Ocampo, 2015).

Argentina's next major reforms occurred in 1994 under President Carlos Menem. This was concurrent with the widespread privatization and deregulation that occurred across Latin America as part of the International Monetary Fund (IMF)-imposed structural reforms resulting from the 1980s debt crisis (Pou, 2000). During this neo-liberal period and subsequent commodity boom, Argentina's mining industry finally gained prominence. This was largely due to a surge in foreign investment into the extraction and exploitation of natural resources (Giarracca & Teubal, 2014). Argentina's welcoming of foreign direct investment to exploit its mineral reserves was an opportunity to recover from its debt and enable the country's economic growth. However, placing high hopes in mining as a chief economic activity does not always lead to the development of the economy. The literature review describes the issues surrounding natural resources and extraction when coupled with development agendas in Latin America.

The economic changes that occurred in Argentina in the 1990s, partly due to the IMF's structural adjustment plan, meant that the country found itself experiencing a sovereign debt crisis by the end of the 1990s (Teubal, 2004). The country's sovereign debt has carried into the last two decades. In 2001, Argentina defaulted on over $100 billion of debt, and Argentines faced the consequences, with 53% of the population living in poverty (Thomas & Cachanosky, 2016; López & Nahón, 2017). Although the country has undergone several political swings that aimed to implement favorable economic policies to repair its national economy (e.g., under the Kirchners as explored in the literature review), its continued reliance on exporting commodities leaves the country in a state of precarity due to the constant fluctuation of commodity prices. At the peak of a new mineral boom defined by the increased demand for lithium, Argentina has been granted yet another opportunity to learn from its mistakes and develop lithium's resource potential as an aid to economic growth. However, as this research demonstrates, Argentina's development aspirations for its lithium mining industry are complicated. While lithium mining may provide the country—and lithium-rich provinces in particular—with opportunities for greater self-determination over their mineral wealth, mining in arid regions also presents localized sustainability issues, particularly around water quality and availability.

## Lithium Mining

### *Source and Processing*

There are two main methods for extracting lithium. The first consists of extracting lithium from rock minerals, and the second involves extracting lithium from brine in salt flats (such as the ones found in "The Lithium Triangle," see figure 3 for reference). Salt brines are the most common type of lithium deposit and make up about 66% of the global lithium reserves (Marchegiani, Hellgren, & Gómez, 2019). Quinteros-Condoretty et al. (2020) argue that obtaining lithium from brine is more desirable than rocks because brine allows for the recovery of lithium carbonate with the degree of purity required to produce lithium-ion batteries. The process of extracting lithium from brine is significantly different from extracting from solid rock; nonetheless, both methods involve two stages to be suitable for export: extraction and processing. I focus on the process regarding brine, since that is the major approach being employed in Jujuy.

First, brine is pumped from beneath the salt flats into a number of large, shallow, open-air evaporation ponds to increase the concentration of brine through evaporation powered by the wind and sun (Talens Peiró et al., 2013; Choubey et al., 2016; Flexer et al., 2018). This form of evaporation (with wind and solar energy) is utilized because of its cost-efficiency, since salt brines are typically found in arid regions and high elevations (Flexer et al., 2018; Kaunda, 2020; Quinteros-Condoretty et al., 2020). Considering wind and solar irradiation are the only energy inputs, the ponds must be very large in surface area, so the water is not too deep (Baspineiro et al., 2020). The water in the ponds will then evaporate slowly and leave the lithium behind, in the form of lithium chloride. Consequently, large amounts of water are lost in the process (Quijano, 2020). Additionally, chemical compounds need to be removed from the lithium chloride before it can be pumped out and transported for processing. These undesirable chemicals include borates and magnesium. Soda ash is then added to the brine concentrate to produce lithium carbonate as a precipitate; this is because lithium carbonate is chemically stable, and versatile for industry-specific utilization such as chemicals or actual lithium metal (Kaunda, 2020). Often, the solid lithium carbonate is repeatedly dissolved and re-precipitated, until it reaches battery-grade purity (which is desirable for export).

*General Water Concerns*

Salt flats are generally found in very arid regions with minimal annual precipitation. Although water in the salt flats can be found in very limited quantities as a mixture of brine and fresh water, the concern over water quantity stems from the fact that more water is being lost through the evaporation ponds than was naturally being replenished into the system (Sticco, Scravaglieri, & Damiani, 2018). According to Acosta and Custodio Gimena (2008), aquifers found at a salt flat consist of the following: a shallow upper aquifer with an intermediate section that forms an enclosed lower aquifer. Both salt and freshwater aquifers exist separately in the salt flats because of differences in density; however, the point of contact between the two is characterized by a saline interface (Holzbecher, 2005). Moreover, damage to the saline interface (through extraction methods such as the current evaporation technology) can potentially lead to the mixing of salt and freshwater aquifers, thus compromising freshwater sources in the area due to salinization (Holzbecher, 2005).

Freshwater aquifers depend on rainfall as the only source of replenishment at their high elevations, and the only natural form of discharge is through evaporation (Acosta & Custodio Gimena, 2008). With higher rates of extraction in both brine and freshwater, the hydrological imbalance could have negative impacts on the salt flat ecosystem, local flora and fauna, and damaging impacts on agriculture in the surrounding areas. Additionally, brine water cannot be used for human consumption, and a decrease in brine water will also impact the quality and availability of freshwater. In 2018, a study on the hydrological balance of the Olaroz extraction site further supported the concerns raised about the sustainability of the brine evaporation techniques (Quijano, 2020). The study concluded with raising the need for a change in current exploitation methods to ensure the equilibrium of the water leaving and entering the system.

### *"The White Gold Rush" in Argentina*

Although Argentina has a history of being resource-rich and being an export-based economy, it does not share the same mining history as its neighbors Chile and Bolivia. The year

1997 marked the beginning of Argentina's lithium mining industry when Fenix, a project in the *Salar Hombre Muerto* in the province of Catamarca, began its operations (see Figure 4 for reference). For over a decade, this was the only commercially operating lithium plant in Argentina. This was largely a result of Argentina's 2001 debt default and its volatile economy in the early 2000s, which decreased its attractiveness for foreign investment. The second project to begin operations was the Olaroz Lithium Project—commonly referred to as Sales de Jujuy—in the Olaroz salt flat in Jujuy, Argentina. In 2016, the Sales de Jujuy project accounted for 6% of global lithium production, marking a turning point for Argentina and its potential to develop its lithium industry (Marchegiani, Hellgren, & Gómez, 2019). Although there are only two projects in commercial stages currently, there are around 60 projects at different development stages, so the national government is highly optimistic for the country to continue being one of the world's top exporters of lithium and see this as a means of recovering from its long history of debt and economic crises (Dorn & Ruiz Peyré, 2020).

In contrast to Chile and Bolivia, Argentina does not have a centralized public policy surrounding natural resources. The national and provincial governments share responsibilities in the management of the country's natural resources (Dorn & Ruiz Peyré, 2020). The provinces of Catamarca and Salta support pro-mining policies, meaning they both opt for a private business-led approach, which is very much dependent on private companies for the extraction and processing of lithium. However, Jujuy's provincial government has a much more interventionist role in mining management to ensure benefits are achieved at the provincial and local levels. Therefore, the success of Argentina's lithium mining industry as a generator of economic growth is contingent on strong provincial frameworks for mining operations.

## STUDY AREA

*The Argentine Puna: Salt Flats (Salares)*

Most arid highlands share several distinct characteristics that determine how they respond to multi-scalar human-induced processes and land system processes. The subtropical highlands of Argentina, known as the *puna,* is a biophysical system that illustrates the interplay of these processes (Izquierdo et al., 2018). Encompassing the lithium-rich provinces of Catamarca, Salta, and Jujuy, the Argentine *puna* covers 95,683 km² at altitudes between 3200 and 6700 m (Izquierdo et al., 2018). The *puna* climate is cold and dry, receiving only between 100 - 400 mm of mean annual precipitation (Cabrera, 1976; Flexer et al., 2018). The salt flats and lagunas found in this region act as vessels to the rivers that flow down from higher elevations. However, most of these rivers are temporary and only form during the rainy season (Marchegiani, Hellgren, & Gómez, 2019). Moreover, the direct rainfall and lateral inflow from these temporary rivers comprise the only water input to the salt flat system because of the arid conditions of the region (Marazuela et al., 2018). Therefore, the Argentine *puna* is a volatile land system due to its limited quantity of water contingent on annual precipitation as the only source of replenishment.

A study on land use trends in the Argentine *puna* conducted by Izquierdo et al. (2018) concluded that the recent increase in lithium mining activity in the salt flats has largely altered the biophysical and cultural landscape. Inhabitants of the *puna* have historically used the land for agriculture and pastoralism. However, the increase in lithium mining projects in the region has reconfigured the use of land and raised questions about the ecological consequences of extraction. With employment opportunities generated from mining projects, people have migrated into these rural highlands, and local inhabitants have switched from traditional farming to mining jobs (Dorn, 2021). As a result of the expansion in mining operations and local inhabitants opting for mining jobs, biophysical systems in the salt flats have been converted to support lithium mining operations. The biophysical composition of the *puna* ecoregion is susceptible to the introduction and expansion of mining infrastructure (such as roads, pumping stations, evaporation ponds) and lithium extractive methods which are unsustainable in the local context. Land change directly associated with surface mining operations causes soil displacement, the clearing of vegetation, alters ecosystem function and services, and reconfigures natural landscapes (Sonter et al., 2014; Abd El Aal et al., 2020). In addition, water systems in the salt flats are largely used for mining purposes, and there is currently minimal regulation on water consumption and contamination in the *puna* region (Marchegiani, Hellgren, & Gómez, 2019). The overall decrease in agriculture and pastoralism is not only due to employment competition, but also the strain on local aquatic systems (caused by lithium extraction methods) resulting in a decrease in vegetation and limited water availability to support pastoralism. Izquierdo et al. (2018) demonstrate that the dry *puna*, a biodiversity hotspot, is undergoing land changes that are yet to be adequately studied, acknowledged, and addressed. These changes occur in the context of globalized demands and a strong influence of state in the management of natural resources and transformation of land use for mining projects.

*Case Study: Sales de Jujuy Project*

The Sales de Jujuy (SDJ) project is a lithium mining project located in the Jujuy Province in Northwest Argentina (the *puna* region).[3] Project facilities are serviced by two paved

[3] Refer to Figure 5 for a map of the province of Jujuy.

highways, RP 70 (to the West) and RN 52 (South). The project operations are at an altitude of about 3,900 m and produce lithium carbonate from the Olaroz salt flat brine resource, which contains high concentrations of lithium and potash brine (Sales de Jujuy). Adjacent to the project operations are the *salares*, Olaroz and Cauchari, which are located in the center of the department of Susques (Anlauf, 2017, p. 170).[4] The area is estimated to be inhabited by almost 4,000 people, who live spatially distributed in a total of ten (Atacama) communities of up to several hundred people each (Anlauf, 2017, p. 170).

In 2009, Orocobre Limited, an Australian mining company, started the preliminary planning of the SDJ lithium mining project resulting from their 2008 sampling and exploration conducted in the brines of the Olaroz salt flat (Orocobre Limited, 2008; Orocobre Limited, 2009). In 2012, it began official construction after the state-owned company, JEMSE, entered the SDJ joint venture agreement with Orocobre Limited and the Japanese Toyota Tsusho Corporation (TTC). SDJ is considered the first greenfield project (beginning from zero) to start operations in the Argentine salt-brines after 20 years (Marchegiani, Hellgren, & Gómez, 2019). The project then entered commercial production in late 2014 and had its first sale in April of the following year. In 2018, Orocobre announced the increase of the Sales de Jujuy Production Plant Stage 2 Expansion to 25,000 tons per year (total 42,500 tons per year) from the previously reported 17,500 tons per year (Orocobre Limited, 2018). Upon receiving approval from the Jujuy provincial government for the expansion of plant construction and new ponds and permissions for brine extraction and access to groundwater for processing, Orocobre documented in their 2019 fiscal year report the successful construction of roads, new evaporation and harvest ponds, and production boreholes (Orocobre Limited, 2019). In addition to building new infrastructure to

[4] Refer to Figure 6 for a map of this project's study area.

make lithium extraction more efficient and to increase production, SDJ also expanded its existing site infrastructure and workforce accommodations (Sales de Jujuy).

The SDJ project has not faced as much local opposition in comparison to other emerging lithium projects in Jujuy and in other parts of Argentina. This is primarily due to the fact that the project generates employment (Dorn, 2021). Given the scale and intensity of lithium mining operations, other development-stage lithium mining projects in Jujuy have faced resistance from local communities to stop operations on their lands or demand a free and informed prior consultation process (e.g., Salinas Grandes legal battle in 2012).[5] Though thus far, the provincial government has not followed through with successfully carrying out or making plans for these consultation processes (Gullo & Fernandez Bravo, 2020).

The involvement of the Jujuy provincial government in the SDJ project through their state-owned company JEMSE and the power that transnational corporations hold over operations diminishes participation by the local stakeholders to the extent of dictating the terms of how operations will be carried out. Although local communities in Olaroz are aware of the potential ecological consequences lithium extractive methods pose, they are largely unaware of the extent of these impacts. The SDJ project offers an opportunity to assess the active role of the provincial government in lithium mining operations and the extent of this role in impacting change on the ground. Because SDJ has been commercially operating for several years, quantifying the extent of surface mining operations presents the opportunity to assess the changes in the land over time. These land patterns are indicators of the provincial legal frameworks and governance structures

[5] In 2012, 33 communities of Salinas Grandes reached the Supreme Court to demand their right to a free, informed, and prior consultation process by any entity who wishes to conduct any form of mining activity in their territories. For more information on the communities in Salinas Grandes legal contestation over lithium mining see Gullo and Fernandez Bravo (2020) and Dorn (2021).

which are fundamental to the effects on local extractive landscapes.

## LITERATURE REVIEW

Since the 1960s, there have been ample scholarly debates surrounding the exploitation of natural resources and the relationship between natural resources and development agendas in Latin America. The following section situates these scholarly contributions and historical threads while also considering the state of global affairs in the development of theory and knowledge, as well as in the construction of new bodies, entities, and structures. Although this section remains broad in scope, the examination of Latin America's struggle to develop its natural resource potential since the 60s provides context for understanding the relationship between Argentina and its neighbors and the issues surrounding extractivism that persist today. In tracing the evolution of theoretical debates on natural resources and expanding mining frontiers as they relate to development, I also illuminate the absence of deep engagement with the biophysical realm in this literature. Given this gap in Latin American development theory and resource geography, I turn to an interdisciplinary framework that builds on the social and environmental sciences and reinforces the need for the stronger integration of quantitative empirical data in these theoretical debates. It is my hope that by putting these ideas in conversation, I can establish a more holistic perspective for assessing the current issues attributed to lithium mining in Jujuy, Argentina.

### Development Imaginaries in Latin America: Natural Resources and Mining

*The Paradox of Plenty*

Although the term “resource curse” was not coined until 1993 (by the British economic geographer Richard Auty) to describe why resource-rich countries typically underperform economically, debates about resources being more of an economic curse than a blessing in developing countries emerged in the 1950s and 1960s.[6] For example, in research on the post-war experience, empirical evidence supported the notion that resource-abundant countries have stagnated in economic growth since the early 1970s, inspiring the term ‘curse of natural resources’ (Wright & Czelusta, 2004). Jeffery Sachs and Andrew Warner presented statistical evidence of an inverse relationship between natural resource-based exports and growth rates during the period 1970-1989 based on a sample of 97 developing countries (Sachs & Warner, 1995). While it has been substantiated numerically, how do we explain this cyclical pattern of under-development by countries with an abundance of natural resources? A number of scholars have attempted to answer this highly debated question. For instance, in the case of Latin America, William Maloney (2002) argues that underperformance and an intense sense of dependence can be found in obstacles to technological acceptance and progress with deep historical roots. As one example, the deficient national "learning capacity," aggravated in the post-war era, prevented the Latin American countries from keeping up with the technological innovations occurring in other parts of the world, such as the United States (Maloney, 2002). Wright and Czelusta (2004) suggest resource-based economies performing poorly is not due to

[6] The concern over the success of resource-based development goes back centuries. For example, Hofman (2000) traces the impact of mineral resources on economic development in Latin America to the colonial period. In recognizing Latin America’s colonial roots, it is also important to acknowledge that issues of unequal income distribution and rural poverty that many Latin American countries—such as Argentina—face today, are premised on the power structure European settlements established (Hofman, 2000). This meant that the wealth generated from resources was confined to specific parts of countries (typically commercial centers), while rural areas remained underdeveloped.

an overemphasis on minerals but rather a lack of appropriate policies to develop their mineral potential. Given the findings of this research on Argentina, the latter argument is compelling. As far as minerals (resources) themselves being a "curse," Wright and Czelusta (2004) say, the curse manifests in places where minerals exist and are shaped by the views (on minerals) of policymakers and corporations—who are the ultimate determinants of development outcomes.

Although this unfortunate phenomenon explains why countries with an abundance of natural resources tend to experience suffering economies, not all resource-rich countries follow the same trajectory as the resource curse may seem to suggest. The United States is a prime example of using its mineral resources for technological innovation and as opportunities for economic growth. Walker (2001) recounts the success story of California's natural resource development—through its innovative extractive technologies and strong government policies, the state was able to use its resource wealth to flourish economically. There is a general consensus that mining (and mineral resources) can foster economic growth, and in some countries, it has, such as Australia, Canada, Chile, Malaysia, Peru, the Netherlands, Botswana, and Norway (Davis & Tilton, 2005). Far prior to the formulation of the term, Latin America has experienced a changing trajectory of the resource curse, from the reversal of misfortune to the repetition of past mistakes related to their attempts to develop their resource potential.

*Mining: Conventional View vs. Alternative View*

Mining holds huge prospects for turning dormant mineral wealth into forms of capital that directly contribute to economic development. Davis and Tilton (2005) explore the issue surrounding policy[7] and an important debate by two opposing views on the relationship between mining and economic development: the conventional view and the alternative view. The conventional view explains the positive relationship between mining and economic development structured from neoclassical economic models (more specifically, the notion of production function). The conventional view recognizes the potential for profit from mineral reserves (as part of the country's stock of natural capital), and even under rare circumstances, a country may postpone the development of its mineral wealth if there are prospects for the value of its mineral wealth in the ground appreciating (Davis & Tilton, 2005). Conventional developmental views focused on economic growth have been based on a top-down approach (technical expertise and bureaucratic authority) which exacerbated the socio-economic equalities this development model aimed to "fix" (Vesalon & Creţan, 2013). On the contrary, the alternative view takes on a more pessimistic approach predicated by studies in the 1980s, which found little to no economic growth in many mineral-rich countries over several decades (see, for example, Auty, 1994). According to Davis and Tilton (2005), the alternative view understands the outcomes of mining as stemming from the following explanations: the prices of mineral commodities are declining in terms of trade, volatile markets make it difficult to rely on revenues from the minerals sector, thus preventing sufficient planning needed for economic development, and lastly, the nature of mining creates unequal costs and benefits for local communities and international corporations.[8] However, in the period of natural resource abundance and economic growth (1970-1990), a

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[7] Since debates about the resource curse, discussions revolving around an effective policy that would ensure economic development from mining in developing countries have been explored by numerous scholars (see Davis and Tilton, 2005).

[8] By unequal costs and benefits of mining, it means that local communities tend to bear the environmental burdens and social costs created by mining, and the benefits/profits are reaped by the central government and international corporations. In addition, often the host country rarely profits from 'market value' because raw minerals (materials) are exported for manufacturing and sale elsewhere.

study by Sachs and Warner (1999) fails to establish any substantial connection between trade volatility and growth. As such, Snider (1996) suggests that political extractive capacity is reflective of political strength, thus pointing to a relationship between political performance and economic performance. In the case of some Latin American countries in the decades that followed the 1960s, political unrest hindered the growth of peripheral areas even as primary commodity exports grew (for example, see Hofman, 2000).

Although it would seem that the conventional and alternative views exist on opposing ends of a spectrum, they do share points of consensus, being that mining can promote economic development under certain conditions such as stable markets and strong governments (as Davis and Tilton 2005 reinforce in their review). However, to best understand the successes and failures of countries' economic development, Davis (1998) suggests that the state's ability to endorse and govern a clear development policy has been a critical aspect of political economists' analyses. Although some scholars (e.g., Mahon, 1992) critique Latin America's dependence on the export of primary commodities in the second half of the twentieth century, some countries were able to economically benefit from resource extraction, such as the case of copper in Chile. Furthermore, no academic insists that mining has never really contributed to economic development, just as no academic claims the opposing extreme, that mining has always supported economic growth. As Salim (2003) puts it, "The historical record of extractive industries in contributing to economic growth has been mixed…" thus, there are no hard and fast rules for determining which resource-rich countries will be prosperous in development efforts and which will be fated with the resource curse.

*Extractive Economies & Exploitation: Dependency Theory*

In the late 1950s, Argentine economist and statesman Raúl Prebisch proposed an approach to understanding economic underdevelopment that focuses on the presumed constraints established by global political and economic order (Munro, 2018). This theory emerged out of Central and South America, but it was part of a larger movement asking many questions about international relations at the time.[9] Similar to the resource curse, dependency theory captured global attention in the 1960s and 70s. Dependency theory focuses on extracting resources from poorer nations to enrich wealthy countries (Kabonga, 2017). Dependency theorists argued that countries were not developing around the world because the international system at the time (during the 1960s and 1970s) was preventing them from doing so. This international system was exploitative and characterized by the dominance of what would have been described as the "First World" at that time (also alternatively termed the "core" by dependency theorists) over what would have been described as the "Third World" (or as the "periphery" by dependency theorists). Countries in the periphery (less developed countries) are understood to have economies focused on resource extraction, agricultural production, and the provision of cheap labor. The periphery countries serve the interests of the wealthier countries. This international system serves the interests of the wealthy (core countries) and does not observe the interests of developing countries in an equal manner. It does not promote development or equal opportunity; instead, it enables dominance and exploitation (of labor). A major hallmark of the approach is that this system is explicitly designed to prevent countries in the periphery from developing (Frank, 1967).

[9] In the 1960s, when the theory of dependency became prominent, one of the questions about international relations at the time was why are so many countries in the world not developing? The traditional answer to the question was because countries were not pursuing the 'right' economic policies or because their governments were authoritarian and corrupt, as many of the Central and South American countries in the 20th century. The Central and South American countries were characterized as countries in the periphery.

A number of Latin American theorists aimed to overcome the limitations that "methodological nationalism" brings to dependency theory.[10] These shortcomings are grounded in the political dynamics of the inter-state system on the exploitation of labor-power and the generation of relative surplus value (Arboleda, 2020, p. 95). Argentine philosopher Enrique Dussel (1988) critiqued the dependency theories that emerged in the 1960s in Latin America because they mistakenly confused the nature of dependency (transfers of surplus value) with its numerous, phenomenal, historical manifestations[11] (Dussel, 1988; Arboleda, 2020, p. 95). Perhaps the most notable approach to dependency was presented by Brazilian economist and sociologist Ruy Mauro Marini. Marini (1973) believed that the capacity of developed nations to build capital-intensive industrial structures oriented towards the development of relative surplus value was focused on the "super-exploitation" of the labor class in undeveloped nations, where production was organized on the basis of the extraction of absolute surplus value from labor-intensive raw material production.[12] In simplest terms, "super-exploitation" occurred during this period in Latin America because many Latin American economies focused exporting their natural resources (ex. Copper in Chile in the 1970s) through alliances formed between transnational corporations and local elites. This created "dependency" on foreign actors to purchase and sell their natural resources, which (as many theorists would agree) placed the

[10] According to Wimmer and Schiller (2002), methodological nationalism is interpreted as the belief that the normal social and political structure of the modern world is the nation/state/society. Moreover, geographer Eric Sheppard defines it as the ontological position that we can analyze nation-states as if they are autonomous, isolated units of analysis.

[11] These historical manifestations are rooted in international political relations.

[12] Super-exploitation refers to the dominant classes in the periphery compensating for their subordinate position in the world market by paying less than its value for labor power. The extraction of minerals in mining is a labor-intensive process that is typically performed by uneducated people who are members of the working class; thus, they often did not know the value of their labor and depended on their jobs as a source of income.

periphery countries (Latin American economies) in a subordinate position. Due to factors, such as lack of education (in the periphery countries), overproduction led to the decrease in the value of resources and commodity speculators generally set lower prices for resources.[13] Lastly, in the context of extractivism, peripheral elites often benefit from extractivist dependency, whereas average citizens and communities are burdened with the consequences of local natural resource extraction.

*Limitations on Exploration Capacity*

In her 1990 book, *Natural Resources: Allocation, Economics, and Policy*, Judith Rees describes the "handicapped" position of less developed countries to undertake extensive levels of mineral exploration on their own. One of the biggest constraints to governments undertaking mineral exploration was capital shortages (Rees, 1990, p. 73). Moreover, foreign debt problems posed a major obstacle to domestic exploration abilities.

Rees's account of limits on exploration capacity in developing countries was reflective of the Latin American debt crisis, which originated in the early 1980s. In the 1970s, several of these labeled "emerging" nations (in Latin America) were given loans to strengthen their economies through subsidizing industrialization. When oil prices shot up over 300% in the 1970s, Latin American economies faced higher import costs, hindering development. Although multiple contributions ultimately led to the debt crisis, one of the main reasons was the significant drop in

[13] In dependency theory, the peripheral countries are subordinate to the core countries because they "depend" on them to buy and sell their products. The hope is that with the export of their natural resources, their economy will grow. However, this was certainly not the case. Peripheral countries were producing more with the intention of earning more money. Overproduction led to lower prices for resources and a continuation of this cyclical nature of dependency.

prices of Latin America's main mineral exports, such as copper in Chile and tin in Peru (Ocampo et al., 2014, p. 34). Amid a global economic recession (in the 1980s), Latin American countries had accumulated more debt than they could pay off, forcing them to turn to the International Monetary Fund (IMF) for loans to help settle their unpaid debt.[14] This monetary assistance was under the expectation that Latin American countries would implement free-market capitalist policies.[15] As a result, public enterprises collapsed, and privatization gained prominence. With extensive levels of debt, difficulties with repayment, and limits on borrowing, developing countries heavily depended on the foreign private sector or joint ventures to finance mineral exploration (Rees, 1990, p.74). Unfortunately, the limits on independent mineral exploration activity further exacerbated the cyclical nature of dependence.

Several scholars have addressed the role of transnational corporations (TNCs) in mineral exploration as a result of the Latin American debt crisis. The slow period of economic growth since the 1980s increased the dependence on foreign direct investment (FDI) for the exploration and exploitation of natural resources (Smart, 2020). In addition to the financing needed to explore, many countries also lacked the technological expertise and infrastructure to access and explore mineral reserves in remote locations, forcing a reliance on the scientific and technical knowledge TNCs could provide. Castells and Laserna (1989) referred to this as the "new dependency" premised on Latin American nations' technological underperformance in the 1980s and their turn to TNCs for technological transfer. However, as Castells and Laserna point out, these companies will not transfer technology if it is not to their own benefit. Therefore, foreign mining companies often dictated the terms of mining operations and the distribution of benefits

[14] Argentina, Brazil, Mexico, and Venezuela were the largest debtor nations.

[15] Under the conditions of the IMF's help to settle Latin American economies debt, poverty and inequalities were further exacerbated.

within the state's regulations (often unregulated). This underlines the power relations embedded in Latin American extractive industries and economies and the struggle to generate domestic economic growth under the constraints of creditors like the International Monetary Fund.

*Extractivism Under Free-Market Reforms: The Neo-Liberal Period (1970s-2000s)*

The neoliberal period (generally understood as the 1970s-1990s) was marked by an approach to extractivism that limited the state's role over the management and extraction of natural resources. According to Rodríguez (2021), starting with the military experiments of the Southern countries in the 1970s (e.g., Perón in Argentina), neoliberal reforms aimed at liberalizing capital and labor markets, reducing state regulatory role in the economy, and privatizing state-controlled industries. In the 1980s and 1990s, this expanded across the Latin American continent in countries like Peru, Colombia, and Venezuela (Rodríguez, 2021). This became the dominant model for Latin American economies as the new world market-oriented developmentalism was directly impacted by the IMF debt loans restructuring conditions (Brand, Dietz, & Lang, 2016). According to Brand, Dietz, and Lang (2016), from 1980 to 2000, the participation of Latin America in world trade dropped below 5.5%, and the export shares of raw material sectors such as mining increased. In the course of structural changes during the neoliberal era, the participation of transnational corporations (TNCs) increased in countries such as Chile and Peru, transforming control over and access to raw materials (Brand, Dietz, & Lang, 2016). At least 14 countries implemented policy changes to TNCs in mining in the 1990s (Cooney, 2016). Because TNCs were key actors in the push for neoliberal globalization, countries with no mining tradition, such as Argentina, could explore previously untapped mineral reserves. As a result, foreign investment in mining exploration in Latin America rose approximately 500 percent between 1991 and 1999 (Cooney, 2016).

However, the exploitation of mineral reserves as a means of generating a profit and promoting development was faced with widespread resistance during the neoliberal period, particularly from those directly impacted by the negative social and biophysical consequences of extraction. According to Kelly (2008), neoliberal reforms were directly associated with increased inequality, poverty, lack of access to social support through programs financed by the state, and weakened democracy. Although this model was under the pretense that the IMF debtor countries would economically develop, it further exacerbated inequalities and burdens at national-subnational-local scales because TNCs would often manipulate conditions for their own benefit or establish relations with state corporations to engage in corrupt practices (Manzetti & Blake, 1996; Saad-Filho, 2005).

**The New Extractivism**

Since the 1970s, several Latin American countries have relied on exploiting and exporting their natural resources to bolster economic growth and pursue development trajectories. This was done through the implementation of neoliberal policies to secure Latin America's position and participation in the world market. In the 21st century, the political, societal, developmental, and ecological implications of Latin America's resource commodity boom have been a subject of debate among scholars. Moreover, extractivism as a mode of development is complicated because it is contingent on the stability of global markets and strong national (and subnational) governance structures, which has rarely been the case for Latin America.

*Neo-extractivism: 2000 to present*

The backlash against the IMF-imposed focus on free-market capitalism in the 1980s led to the election of progressive-left wing governments across Latin America in the 1990s and 2000s, known as "The Pink Tide." The trend started with the election of Venezuelan President Hugo Chávez in 1999. In the early 2000s, this spread to Brazil, Paraguay, Chile, Uruguay, Ecuador, Peru, Argentina, and Bolivia. The election of progressive governments lasted for over a decade. This period is best illustrated by Argentina's *Kirchnerismo,* which began with the election of populist leftist president Néstor Kirchner in 2003, fostering an era of social progressivism and economic nationalism (Wylde, 2011). Contrary to the neoliberal model of the 1990s, Kirchner maintained strict controls by drumming up nationalist sentiments from the previous reforms and strengthening power in the executive branch. This progressive attitude persisted with the presidential election of his wife in 2007, Cristina Fernández de Kirchner. However, Stefanoni (2019) affirms that *Kirchnerismo* is largely criticized for corruption because of their shady handling of multi-million-dollar budgets, which resulted in the country defaulting on its debt.

The election of left-wing governments across Latin America led to the growth of social organizations and social movements (which also played a role in their election) and were often incorporated in decision-making processes, especially related to natural resource extraction. According to Veltmeyer (2012), more than a few analysts have viewed this development (referring to the Pink Tide) as the "beginning of the end of the neoliberal," paving the way for a new world order defined by social justice and sustainable development. Veltmeyer (2012) states that others have been quick to critique these "post-neoliberal" regimes, given their turn towards natural resource extraction and primary commodity exports as a national development model.

Alongside favorable commodity prices in the 2000s, Latin American economies deployed a "reprimarization"[16] growth strategy, meaning state officials restored a focus on the economics of resource extraction but within the regulatory framework and management of the state (Veltmeyer, 2012). McKay (2019) asserts the consensus among critical development scholars around, neo-extractivism, or el *nuevo extractivismo*, is that the interventionist, progressive state continues to rely on expanding extractivist frontiers. Simply: like many other pre-fix terms, neo-extractivism is a way of indicating a contemporary rendition of extractivism. In the neo-extractivist model, the state plays a much more active role than the classic extractivist model, where the state is less involved in the economic flows to which natural resources give rise (Merchand Rojas, 2016). In the context of neo-extractivism, the state partially rejects neoliberal policies and regulates the appropriation of resources and exports by (in some cases) modifying contracts, nationalizing companies and natural resources, and increasing export duties and taxes (Burchardt & Dietz, 2014; Brand, Dietz, & Lang, 2016).[17] The transition to a more state-led model of extractivism has also realized processes of state modernization or development projects through the creation of legal frameworks, new institutions such as ministries for mining, and

[16] Reprimarization refers to the return to primary commodities as the main source of export revenues. More information on reprimarization through neo-extractivism can be found in Brand, Dietz, and Lang (2016).

[17] This occurred with the election of progressive left governments (*The Pink Tide*) in their efforts to intensify control over natural resources. Contrary to the old extractivist model geared towards "exports" or the "world market," the progressive governments have replaced this vision with one that favors "globalization" and "competition" under its own terms (Gudynas, 2010).

structures of democratic control around the extraction of natural resources and associated processes (Gudynas, 2014; RLIE, 2016). With the increased political power of institutions (within the jurisdictions of the state) linked to extractivism, granting the necessary infrastructure to support mega-mining projects, countries like Argentina (from the late 1990s onward) were able to intensify the extraction of natural resources, increase taxation, and manage exports abroad (Grugel & Riggirozzi, 2012; Gudynas, 2014).[18] Alongside the additional income coming from the increased extractive activity (such as the growth in mining industries), governments were able to finance social and development programs. Large-scale mining projects also generated employment opportunities for both rural areas and urban centers. While the classic extractivist model was defended as a means towards economic growth, neo-extractivism often appeals to discourses of progress and national development (Svampa, 2019). Thus, in the model, the state must intervene to facilitate and expand extractivism as the means to obtain financial resources to subsidize plans and programs for development.

However, one of the controversies at the core of this model is the negative impacts neo-extractivism has on the social, biophysical, and political environment. This is important because states often have mandates to protect water quality, endangered species, indigenous communities, and the integrity of landscapes. These negative impacts are important, first, because they augment dependence on the state and its social programs. Secondly, the intensive exploitation of non-renewable resources (ex. minerals) causes significant damage to various Latin American biophysical systems. As a development model, neo-extractivism is premised on the appropriation of nature, which means turning natural resources into commodities for the

[18] Although these emerging political institutions like ministries of mining were able to grant (in some capacity) infrastructure for mining projects, this does not necessarily mean financial means. States were still reliant on foreign investment from transnational corporations or through joint ventures as because they are only entities equipped to provide the financial means to construct large scale mining projects.

global market (see, for example, Córdoba et al., 2017). However, the destruction of environments attributed to intense extractivism has led to various social and political conflicts, and consequently, tends to undermine support from the people favored by this mode of development (Burchardt & Dietz, 2014). Local communities opposed to intensive exploitation of mineral resources have questioned the state's legitimacy due to the negative implications of neo-extractivist policies and projects. Moreover, the critics of neo-extractivism faced the greatest challenges in Latin America because they were labeled "enemies of social change," which resulted in the marginalization of human rights and environmental activists (Cosci, 2014). This model, adopted by centralized governments, diminished opportunities for participation at the local level because decisions were made by the major stakeholders (the federal and/or provincial state and foreign investors). Regarding environmental concerns related to extractive activities, progressive governments have typically repeatedly denied, minimized, or presented these as various issues, thereby rendering the extent and severity of ecological consequences unclear (Gudynas, 2010). As a logic of development promoted by the state, Bridge (2017) shares the concern of other Latin American scholarly critiques that "…have tended to be skeptical of efforts to promote development through the extraction and export of mineral resources or to argue that its ability to do so is contingent on a specific set of institutional, technological, and environmental conditions." In Argentina and other Latin American countries (broadly), current lithium mining projects and state-led development trajectories have been dependent on the aforementioned favorable conditions and are rarely equally benefiting all stakeholders involved. Therefore, neo-extractivism as a development project often implies short-term benefits at the expense of long-term ecological damage.

The neo-extractivism literature has tended to focus on the national government as an interventionist force in mining projects in pursuit of socio-economic development agendas. In the case of lithium mining in Argentina, national interests do not entirely dictate the terms of the exploration and exploitation of mineral reserves in the country. In contributing to this literature, I shift focus to the role of the provincial government in carrying out mining activities and mitigating environmental concerns. Following this concern, the neo-extractivist literature and previous Latin American natural resources and mining theoretical debates lack the quantitative empirical methods to measure the extent of environmental impacts attributed to mining operations. This absence in the theoretical debates points to the importance of interdisciplinary work to connect these strands of literature to scientific methods to assess how human processes translate to environmental changes.

**An Integrated Approach: Land Use Change, Teleconnections, and Remote Sensing**

The intensive exploitation of natural resources in contexts where biophysical impacts are poorly understood or often ignored requires engagement with scholarship that can measure or quantify those changes. In the last two decades, interdisciplinary scholarship has made great strides in using scientific approaches to assess the interactions between biophysical (land) systems and human systems.[19] Land systems science (or land change science) is an interdisciplinary field that aims to understand the causes and consequences of land transformation, including both changes in land use and in the physical properties of the land surface (Meyfroidt, 2015). Studies in Land Systems Science (LSS) have often had a general

[19] Interdisciplinary fields focusing on human-environment relations are among (though not limited to) political ecology, urban ecology, sustainability science, environmental studies, and resilience ecology.

focus on causal analysis: causal effects and causal mechanisms in the attempt to explain a biophysical outcome (see, for example, Bruggeman et al., 2015). However, the debates in the appropriate terminology in LSS, as discussed by Meyfroidt (2015), has led some scholars to use the terms "drivers" and "driving force" as an approach to causality, which are factors that are the hypothetical causes of environmental change with *some* evidence of the outcome, but not enough to establish a firm causal relationship (e.g., Geist & Lambin, 2004; Dearing et al., 2010). In Turner (1989), "human driving forces [of change]" are the proximate sources of change and consequently, result in the alternations and transformations of biophysical landscapes. These proximate causes are often associated with human land use activities, such as mining and agriculture. Since drivers are often used in the context of human-induced factors, this term is also appropriate for describing the variables for environmental and statistical modeling (Serneels & Lambin, 2001). However, it is worth recognizing that human forces may not necessarily be the only drivers of change but rather in combination with underlying factors such as the biophysical composition of the land. In LSS, drivers of environmental and social and change may be related to land systems processes or socio-ecological processes; however, this does not imply a direct causal effect to change.

Land Systems Science focuses on coupling human-environment systems because it is not just one factor driving land [use] change, but rather a configuration of multiple factors interacting. Expanding on and challenging (to an extent) some of the prominent theoretical notions within LSS, the teleconnections framework was proposed to direct explicit interactions between land systems (Friis et al., 2015). More specifically, teleconnections have been used to describe distal environmental and socio-economic drivers of land system change (Friis et al., 2015). For example, teleconnections can be illustrated in terms of a specific place-based problem and use this problem to define system boundaries and connections to other systems (Baird & Fox, 2015). Likewise, teleconnections can be understood within a network of actors and their activities associated with land use and not exclusive to a particular landscape (Baird & Fox, 2015). Finally, a teleconnections framework is used to characterize how particular patterns in the biophysical composition and configuration of the land can be indicators of distal drivers at varying scales.

Teleconnections can be used to explain how land use in one place is caused by consumption originating from another place. For instance, as areas urbanize, the demand for raw materials (ex. metals and minerals) increases; thus, mining activities for construction materials are a major driver of land change in rural places (Güneralp, Seto, & Ramachandran, 2013). Moreover, the teleconnections framework allows us to identify land use consequences of specific demands from different places (at global-national-subnational scales) and analyze the direct and immediate causes as well as broader and more diffuse causal relations in land system change (Friis et al. 2015). The attention to multiple scales allows this framework to be utilized by a variety of academics, such as Geographers interested in studying multi-scalar phenomena. Friis and Nielsen (2017) indicate that changes in policies or changes in governance structures and global demand influence the outcome of land use and land cover change to an increasing extent. Although land use and land cover changes caused by socioeconomic and biophysical factors are often combined to describe the transformations of landscape composition and configuration, it is important to differentiate the two (Marinelli et al., 2021). Land cover describes the physical features that cover the earth's surface, while land use refers to how humans use the land (Jacobson et al., 2015; Lechner et al., 2019). As Lechner et al. (2019) further emphasize, these differences are also critical for quantifying and understanding socio-environmental change in resource development locations.

The use of remote sensing applications to explain patterns of land use change as it relates to mining operations is increasingly being used to assess environmental impacts (Mckenna et al., 2017).[20] Karl Zimmerer (2015) suggests that scientific methods and environmental understandings cannot be separated from the political, economic, and social conditioning of ecological issues. Likewise, Robbins (2012) and Walker (2005) contend that social science research that engages with the biophysical realm is strongest when data is directly integrated into empirical work. The teleconnections framework offers an integrated approach to assessing the changes in mining footprints as mining is characterized as one of the most intensive sources of social and environmental disruption (Hilson, 2002). The ability to map and monitor changes in mining activity is critical to understanding and controlling the potential social and ecological effects (LaJeunesse Connette et al., 2016). Remote sensing technology offers a powerful set of tools to quantify the environmental impacts attributed to mining.

Through combining the theoretical debates surrounding natural resources and biophysical data, I identify the large-scale land use transformations needed to support lithium mining operations and assess change over time using remote sensing. Since mines open, close, and undergo periods of expansion as the economics of production change due to commodity booms, advances in processing technology, and political swings, the intensity of impacts will vary over time (Lechner et al., 2017). As demonstrated in the mining and natural resource debates in Latin America since the 1960s, the shifts in economic markets and changes in governance structures have driven the expansion of mining frontiers. The more recent literature has attempted to

[20] Remote sensing is the process of collecting data about objects or landscapes without coming into direct physical contact with them.

address the ecological transformations attributed to intense mining but acknowledges that governments poorly understand these changes. Teleconnections provides a lens to assess these quantifiable changes in the biophysical composition and configuration of the land for anthropogenic use as indicators of shifting political and economic flows distal to the site of the lithium mining operations.

## A CASE OF NEO-EXTRACTIVISM? LITHIUM MINING IN JUJUY

As the new wave of extractivism continues to unfold in Latin America, and with the growing demand for lithium to aid in the global energy transition, Argentina's work to develop its lithium mining industry presents a unique case study. Contrary to the contemporary neo-extractivism literature in Latin America, which focuses on the role of the national government as the interventionist force for mining expansion, this case study offers a new perspective on the neo-extractivist model operating at the provincial level. The following section highlights how national interest trends can either resonate with or not necessarily align with provincial interests. First, I articulate the relevant national policy changes beginning in the 1990s that broadly enabled the expansion of mining exploration and exploitation in Argentina. Secondly, I outline the major legal frameworks and structural changes in Jujuy that drove the development of lithium mining operations in the province. As the neo-extractivism literature suggests, when the state is an interventionist force in mining operations, it often overlooks the negative social and biophysical implications of extractive activities. I discuss these issues as they relate to Jujuy's provincial governmental commitment to continue operations in the Olaroz salt flat region. In highlighting these issues, I echo critiques that articulate the problematic nature of pursuing development agendas through the intense exploitation of minerals, such as lithium.

**Mining Governance Structures: National and Sub-National Tensions**

The growth of Argentina's mining industry in the 21st century is mainly related to the provisions in the 1993 Mining Investment Act, which promoted foreign investment, thereby bolstering the development of large, opencast mining operations, also known as *megaminería* (Forget, 2015).[21] This form of operations paved the way for Argentina's highland territories (Salta, Catamarca, and Jujuy) to be viewed almost solely as reservoirs of raw materials, overdue for intensive mining (Forget, 2015). The Mining Investment Law (24.196 / 93) is characterized as the "promotional regime of the mining sector" because it grants tax stability, exemption from payment on all imports on capital goods, deduction of exploration expenses from corporate income tax, and an upper bound of 3% for all Provincial Royalties (MDPA).[22] The three lithium-rich provinces with mining operations at different stages have been supported by the Argentine government's legal and political frameworks for the expansion of mining projects. This is further reinforced at the provincial government level because, under the constitutional reforms of 1994, the provincial governments were given complete ownership of natural resources located in their territories and the responsibility for determining and coordinating how to exploit them within the

[21] Megaminería is synonymous with mega-mining projects. It is important to note that the extraction of lithium is not opencast mining. Refer to the section under lithium mining for more information about specific lithium extractive methods.

[22] Although mining took place in Argentina during the 19th and 20th century, it was never the country's principal economic activity. Former president Carlos Menem deepened Argentina's neoliberal reforms in the 1990s. This included the introduction of new mining legislation that improved the benefits to transnational corporations.

regulatory framework of the Argentina Mining Code (AMC). The National Mining Code (AMC) establishes regulations between the state and those who develop any kind of mining activities (individual or legal entity) through an exploration permit or a mining concession (Martinez & Heredia, 2020).[23] Mining regulations may also be found in the Proceedings Mining Codes in each of the Argentine provinces, which outlines the procedures for obtaining legal concessions (or mineral rights) and other legislation that administers effects of mining activities such as environmental regulations.

However, the ownership of natural resources has been an area of contention and one of the reasons why it is only recently that Argentina experienced an expansion of lithium mining operations. In the 1990s, Latin America (broadly) increased its mining operations due to the implementation of neoliberal policies under former president and Peronist leader, Carlos Menem.[24] In addition, the demand for raw materials from emerging industrial centers around the world stimulated the growth of mining projects.[25] Between 2004, when the National Mining Plan came into effect, and 2007, when Néstor Kirchner served as president, the Argentine government's position was pro-mining; although, provincial legislatures were able to reinforce or undermine this position (Comelli, Hadad, & Petz, 2010; Forget, 2015).[26] Under Néstor Kirchner, the number of mining projects increased roughly 800%, and accumulated investments rose nearly 490% (Gudynas, 2010). During Cristina Fernández de Kirchner's presidency (following

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[23] The National Mining Code (AMC) enables concessions for the exploration of mineral reserves and development of the necessary infrastructure to support mining operations.

[24] Carlos Menem is considered to be Argentina's first elected Peronist leader since Juan Perón in 1973. Menem served as president from 1989 to 1999.

[25] The demand for raw materials in Latin America broadly originated from the emerging industrial centers in places like East Asia (Arboleda, 2020, p. 10).

[26] Following Nestor Kirchner's election in 2003, the National Mining Plan was drawn up in that same year, in an effort to turn mining into a model of economic growth (Forget, 2015).

her election in 2007), her government changed the state's position with respect to transnational companies by re-nationalizing former state enterprises that had been privatized during the neoliberal period of the 1990s, and in 2011, by imposing a new round of controls on capital to keep currency in the country such as, repatriation (Forget, 2015). Finally, when former president Mauricio Macri came to power in 2015, he rolled back all of Kirchner's anti-liberal policies to again welcome foreign investment to finance mega-mining projects. Therefore, investment in lithium exploration and production in Argentina experienced a large increase by about 928% between 2015 and 2018 after Macri removed currency and capital controls and abolished the taxes on exports (under Decree No. 349/2016) introduced by his predecessors (Roth, 2019). These minimal restrictions create favorable conditions for foreign investment thereby enabling the growth of the lithium industry in Argentina. This has persisted under the current Argentine president left-centrist, Alberto Fernández, who has expressed support for the lithium mining industry's growth and intends to increase country-wide production from 40,000 metric tons of lithium carbonate to 230,000 metric tons by the end of 2022 (Gonzalez, 2021). Although the national government's optimism and less-restrictive economic and legal frameworks are beneficial for foreign investors in mining projects, the provincial governments must dictate the terms of exploration and exploitation activities according to their own laws and regulations.

**The State as A Legitimizing Force: Jujuy's Provincial Government**

Among Argentina's provinces, Jujuy contains some of the country's largest lithium reserves and accounts for most of the country's current lithium production. Located in the rural periphery of Argentina and bordering Chile and Bolivia, Jujuy has faced a more staggering development trajectory in contrast to other parts of the country like Buenos Aires. Local inhabitants of Jujuy, specifically in the salt flats, have historically relied on agriculture and pastoralism as their only source of income. However, with recent shifts in economic markets and changes in governance structures that support pro-mining policies, Jujuy's government has aimed to develop lithium's resource potential through facilitating the exploration and exploitation of its lithium reserves.

While accounts for the inspiration behind Jujuy's interventionist spirit remain limited, Fornillo (2015) discusses that testimonies support the assertion that the state's interest in promoting the industrialization of lithium is attributed to Cristina Kirchner's state-led model of development. According to Fornillo, in 2010, former president Kirchner attended an inauguration of a General Motors plant, and upon seeing an electric car exposed, she prompted the question, "Why don't we make batteries here?" Quoting the version by Arnaldo Visitin, "Promoting work with lithium is suggested by President Cristina Kirchner" (Fornillo, 2015). This attention to the development of lithium by the national government motivated the provincial government of Jujuy to industrialize the resource.

The beginning of the industrialization of lithium is marked by Jujuy's Provincial Decree 7592 of 2011 (ratified by Law 5674), modified by Provincial Decree Agreement 9194 of 2019 (ratified by Law 6138) which, "declares mineral reserves that contain lithium as a resource natural strategic generator of the socio-economic development of the Province of Jujuy." Under Decree 7592, in order to be approved or rejected, lithium projects had to have a joint resolution of the minister of production and the Secretary of the Interior, approval of the Provincial Directorate of Mining and Energy Resources, the prior procedure of the UGAMP (Unit of Provincial Mining Environmental Management), and a favorable recommendation from the

Committee of Experts for the Comprehensive Analysis of Lithium Projects (Morales, 2019). A more recent law (Law No. 6138 / 19) adds an additional procedure for the exploration and exploitation of lithium, which is a comprehensive environmental impact study to monitor and mitigate the impacts of lithium mining. Although the more recent law enables the provincial government to further facilitate the process of environmental impact studies, Morales (2019) claims this process favors multinationals and mining companies, and it only reduces it to evaluation by the UGAMP.

Jujuy's long-term investment in lithium extraction goes beyond the benefits of resource wealth. They intend to use this as an opportunity to subsidize research, technological and industrial development (Dorn & Ruiz Peyré, 2020). Although Jujuy's government has remained committed to expanding its mining sector and ensuring direct benefits are achieved at the local level, they cannot finance the development of large-scale mining projects on their own. The absence of [national] restrictions pertaining to foreign investment in and the ownership of companies involved in the exploration and extraction of mineral resources means the provinces negotiate concessions directly with mining companies and tend to opt in favor of international and transnational corporations and/or enter joint venture agreements (Forget, 2015).[27] This is because they are the only entities with the capability of providing the finances needed to construct mega-mining projects.

In 2011, the provincial government of Jujuy (under Decree 7626) created JEMSE (Jujuy Energía y Minería Sociedad Del Estado) to have the same operational and executive characteristics of a private company, with the main objective of promoting the economic development of the province with public-private [mining] partnerships. The government founded

[27] This absence of national restrictions pertaining to foreign investment originates from the 1993 Investment Act.

JESME to have direct intervention and participation in emerging (at the time) and future mining projects in the province. Decree 7626 states it is necessary to find a legal regime that allows the state to achieve and study the prospecting, exploration, exploitation, development of minerals, hydrocarbons, and energy. With the declaration of lithium as a strategic resource and the creation of JEMSE, Jujuy's provincial government justifies the intensification of lithium extraction as the means to pursue social and economic development of the province.

## JEMSE

### *The Olaroz Lithium Project or Sales de Jujuy*

The Olaroz Lithium Project (Joint Venture) is operated through the operating company, Sales de Jujuy S.A. The shareholders are Sales de Jujuy Pte Ltd (a Singaporean company that is the joint venture vehicle for Orocobre (Australian company), Toyota Tsusho Corporation (TTC, Japanese company), and JEMSE. The effective Olaroz project equity interest is Orocobre 66.5%, TTC 25.0%, and JEMSE 8.5% (Orocobre Limited, 2013). As mentioned previously, the provincial government of Jujuy founded JESME in 2011 to be directly involved in the decision-making process and to obtain greater revenues (Dorn & Ruiz Peyré, 2020). However, to achieve the 8.5% shares JESME holds in Sales de Jujuy, JESME went into debt with Orocobre and Toyota Tsusho. JEMSE's share was obtained through an interest-free loan for its capital contribution and will be repaid with one-third of the anticipated dividend stream to JEMSE (Orocobre Limited, 2013). In addition, the stake in Sales de Jujuy gives JEMSE the priority of sale over a 5% share of the lithium carbonate that the company produces, which can be sold or used in Argentina (Fornillo, 2015). The project currently produces 17,500 tons of lithium carbonate per year and projects expanding its capacity to 42,500 tons (Gobierno de Jujuy, 2019).

Although Jujuy government's stake in the project was to be directly involved in the decision-making process and ensure benefits for the province, its marginal share (a class B share) in Sales de Jujuy limits its control and management of the mining operations.[28] Toyota Tsusho acts as an exclusive agent to market the lithium carbonate production from Olaroz. According to Orocobre's 2012 Quarterly Report of Operations, "JEMSE will provide key construction assistance services to the Olaroz Project, and will take a leading role liaising with municipal, provincial and national government departments and customs authorities." Essentially, JEMSE serves as the legal entity to obtain necessary permits in compliance with provincial laws for the construction of infrastructure to support lithium mining operations (plant site, roads, evaporation ponds, pumping stations, etc.) which is, of course, beneficial for Orocobre and Toyota Tsusho for a smooth flow of operations in Jujuy.

However, aside from the JEMSE's limited "voter rights" and profits from Sales de Jujuy, the mining project has generated employment opportunities in an area that is desperate for alternate forms of income. In Jujuy, it is estimated that there are about 2,000 jobs directly related to lithium mining; moreover, Sales de Jujuy claims to employ 385 salaried workers and 460 others through contractor companies (Dorn & Ruiz Peyré, 2020).

*Collaboration with The National University of Jujuy*

[28] Generally, class B shares are distributed by corporations as a class of a common stock (a form of corporate ownership) with less voting rights and a lower dividend priority than class A shares—another class of a common stock with enhanced benefits (Hayes, 2020).

Although the Dr. Horacio Carrillo *Escuela de Minas* (School of Mines) at the *Universidad Nacional de Jujuy* (National University of Jujuy) was created by the Jujuy provincial government decades before discovering its lithium reserves, the recent collaboration between JEMSE and the university has played a key role in lithium mining operations. Given the highly intensive and technical nature of all stages of lithium development (from exploration of reserves to extraction and processing), Jujuy has training establishments for mining technicians and specific university courses aimed at carrying out research and development activities along the entire value chain (Lóndero, 2014; Obaya & Pascuini, 2020). Jujuy's benefit from the university's academic offerings fulfills some of the requirements of the lithium mining sector, specifically related to scientific and technological development to increase the value of lithium products (Lóndero, 2014). Technical training at the university can also minimize the outsourcing of laborers. This allows for the application of knowledge directly generated in the province and garners support from the provincial public sector aligned with lithium and the vision of development.

**Complicated Development Imaginaries: Investment in Short-Term Benefits and Conflicts**

With the increased global demand for lithium stimulated by the surge in electric vehicle production and consumption, Jujuy has seized the opportunity to not only contribute to the global transition to a green future, but also improve economic and social conditions in the province. In a 2019 interview, the president of JEMSE stated, "I have no doubt that our province is destined to play a key role in the coming years, which will be marked by the abandonment of fossil fuels" (Gutman, 2019). In addition to the Sales de Jujuy project generating local employment, with many more employed indirectly through our local contractors and suppliers, Orocobre, Toyota Tsusho, and JEMSE are committed to enabling a low-carbon future (in spirit of the United Nations Sustainable Development Goals). Project officials (from Orocobre and TTC) also target community initiatives. For example, 2019 included the inauguration of the Olaroz Technical School in collaboration with the provincial government, as well as the construction of a Music Hall and Chemistry Laboratory providing additional cultural and technical educational facilities for the local community near the site of Olaroz operations (Orocobre, 2019).

However, the short-term benefits the provincial government of Jujuy achieves through its intervention and support of lithium mining are contingent on the success of the projects they are directly involved in and the stability of economic markets for lithium. JEMSE's small stake in the Sales de Jujuy project suggests that it is profit-driven rather than the desire to have *full* control over operations. This is further reinforced by Fornillo (2015), who claims that JEMSE is far from being constituted with a vision of the future that allows it to be the key to development of both lithium and innovation (as it claims on its website). Instead, it seems to be tied purely to the role of "doing business" (Fornillo, 2015). Arboleda (2020) proposes, "the debtor begins to think individual terms and prioritizes short-term benefits, 'while surrounding sociocultural and ecological considerations secondary'" (p. 201). In the case of the provincial government, the short-term benefits lithium mining can generate for the province appear to be at the expense of ecological crisis at the local level or in the areas surrounding the sites of extraction.

Through the justification of lithium mining as a development project, Jujuy's government has remained optimistic about the lithium industry's potential to be a socio-economic benefactor and has addressed local skepticism and concern over the costs of this development model through environmental regulations and applicable authority.[29] In Jujuy, the biggest concern is the effects lithium extractive activity has on water quality and quantity in the Olaroz (and other mining) areas. For example, the common method of extracting lithium from natural brines results in the loss of about 95 percent of the brine-extracted water, and consequently, the depletion of natural aquifers (Kaunda, 2020). In addition to the immense amount of water that is used (and lost in the processing stage), lithium must undergo a series of chemical processes to be converted into a form desirable for export. The Provincial General Direction of Water Resources is responsible for monitoring water usage in a form that is sustainable. Furthermore, they oversee the concession and control of water use in mining operations in accordance with the disposals of the Provincial Water Code and in association with the Mining Secretary (Marchegiani, Hellgren, & Gómez, 2019). Article 63, paragraph 3, of the Water Code, specifies that water used in mining operations must be returned in such a way that it cannot affect third parties, in this case, local communities. Article 27 of the Water Code also orders the extent to which water access is granted must be specifically quantified and therefore controlled by the implementing authority, General Direction of Water Resources (Marchegiani, Hellgren, & Gómez, 2019). Although these different roles exist to ensure sustainable mining operations, the agencies rarely work together or collaborate adequately (Marchegiani, Hellgren, & Gómez, 2019). Finally, even with the research carried out by the National University of Jujuy, the hydrogeological studies of the salt flats have

[29] In Jujuy there are both provincial and national environmental regulations: Provincial Constitution (art.22), Water Code of Jujuy, Law 3820 Wildlife Reserve of Fauna & Flora, Law 6002 Dangerous Residues Regulation, Decree 5772-P- 2010, Provincial Environmental Law No. 5063, National Constitution (art 41), General National Environmental Law No. 25.675, National Law 24.585 and National Law 24.051 Dangerous Residues Regulation. The applicable authority in Jujuy is the Provincial Department of Mining and Energy Resources (*Dirección Provincial de Mineria y Recursos Energeticos*) and the Provincial Department of Environmental Quality (*Dirección Provincial de Calidad Ambiental*). In compliance with the national framework, the mining projects must complete Environmental Impact Assessments (EIA) every two years.

ultimately been under the responsibility of the companies, which limits the public nature of their results, beyond what is required by current provincial regulations (Obaya & Pascuini, 2020).

In neo-extractivist contexts, the development outcomes achieved through the exploitation of a mineral resource with direct intervention by the state are often contested by those who suffer the environmental burdens. Although if successful, lithium mining (and the profits generated) could contribute to the socio-economic development of Jujuy, as some local communities have already seen. However, the long-term consequences of lithium mining in an area where water is already a scarce resource (due to aridity and highly elevation) have meant that impacted communities are questioning the motives of both transnational corporations who invest in their province and the state which governs them. On the Olaroz salt flat, not all communities have their land directly affected by a project, but rather share the environmental burdens indirectly due to the impact on a shared water source (Marchegiani, Morgera, & Parks, 2019). Mining companies only consult communities they consider to be in a "direct area of influence" and do not consider the communities that are being indirectly affected because they depend on the same water basin (Marchegiani, Morgera, & Parks, 2019). "Areas of direct influence" are ultimately designated by mining companies, and the legal parameters of resource management put forth by the provincial government. Those employed by mining operations often support this approach of development through extraction. However, for other inhabitants of the area of the Olaroz salt flat, "mining companies are synonymous with dispossession and new violence scenarios" (Gullo & Fernandez Bravo, 2020). Organizers that oppose lithium in the area have already faced violence, by both mining employees and indirectly, by Jujuy's government. One of Jujuy's residents organizing against lithium said in an interview conducted by Gullo & Fernandez Bravo (2020),

> "The people of the company and part of the community pointed at us: They said that we were rebels, that we didn't let them work. Even Governor Gerardo Morales said that those of us who were against lithium mining had to stop using cell phones. We asked ourselves, so, are all those in favor of mining going to stop drinking water?"

This local testimony illustrates the complexity of extractivism as a state-led development project. It creates tensions not only between local communities, the state, and transnational corporations, but within local communities themselves. Although lithium can offer a path towards Jujuy's socio-economic growth, the social and ecological impacts attributed to lithium mining suggests this model is more flawed than the Jujuy's provincial government proposes.

**Jujuy's Neo-Extractivist Model of Development**

Since Argentina's lithium mining industry is currently monopolized by transnational corporations and joint ventures, this section offers a closer look into the role of the state as both an actor and stakeholder. Jujuy's investment in lithium mining is to create better socio-economic conditions for the province. However, their participation and control over its mineral resources and mining operations fall short of the finances needed to construct mega-mining projects and develop lithium's resource potential. Therefore, the Jujuy government still relies on foreign investment. The complex power dynamic created as a result of the tensions between the control and management of mineral resources and the costs and benefits that follow suggests that the state as an interventionist force (even under justified pretenses) needs to ensure transparency, equity, and participation among all the stakeholders of mining activities.

While lithium mining operations and the impacts and multi-scalar connections it produces continue to unfold in Jujuy, the creation of JEMSE and support of the expansion of mega-mining operations through a logic of development aligns with the neo-extractivist framework. Although lithium's fully developed potential in Jujuy can certainly contribute to the long-term success of socio-economic development programs, the trends of past and present events (as it relates to my case study) raise concerns about the ecological and social issues attributed to the extraction of natural resources through a vision of development, as the contemporary neo-extractivism literature suggests (Gudynas, 2010; Svampa, 2019).

In any analysis of extractivism, the scale and intensity of extraction must be considered. The mineral booms of the 1970s and present highlight the exhaustion of environmental limits, and how demand, legal frameworks, and governance structures drive issues at the local scale (the area of extraction). However, in my review of the neo-extractivism literature, the specific extent to which the biophysical landscape is affected by mining operations remains underexplored. Although Jujuy's provincial government has acknowledged *some* of the environmental concerns arising from lithium extractive methods, the recent expansion of the Sales de Jujuy project operations demonstrates negligence to fully comprehending the extent of environmental impacts in the Olaroz region. Much contemporary literature on the environmental impacts (and socio-environmental conflicts) of lithium mining in Argentina lacks quantitative data to identify how socio-political-economic processes translate to concrete, biophysical changes on the ground (for example: Anlauf, 2015; Marchegiani, Hellgren, & Gómez, 2019; Dorn & Ruiz Peyré, 2020; Ruiz Peyré & Dorn, 2020). In the attempt to fill a gap in this literature, the following section quantifies the ground changes driven by the neo-extractivism mode of development in the case of the Sales de Jujuy project.

## THE BIOPHYSICAL CHANGES OF NEO-EXTRACTIVISM

The environmental impacts of lithium mining in the Argentine *puna* require further quantitative empirical research. Mining requires extensive surface transformations in all the stages of project operations, from plant development to expansion. Land use conversion to support lithium mining operations is accelerated by national and provincial policy trends and the global demand for lithium, as demonstrated in the case of Jujuy. The ability to quantify these changes is essential to identify the extent to which distal human forces interact with biophysical systems and understand the potential long-term ecological consequences of surface changes in the *puna*. The purpose of this study is to demonstrate the large-scale land use transformations needed to support the Sales de Jujuy (SDJ) lithium mining operations and to assess change over time using remote sensing technologies.

### Methodology

Although there are many methods available to assess temporal changes in land use, this study uses high resolution open-source images to perform on-screen digitization (also referred to as heads-up digitization) techniques for the best identification of SDJ mining operations supporting infrastructure. This technique involves the delineation of features as presented on a map. Often, the spatial resolution of satellite imagery is the main limitation for mapping, which dictates the precision and accuracy (Warnasuriya et al., 2018). Google Earth Pro (GEP) imagery is recommended as a cost-effective and high accuracy method for land use mapping of larger scales due to its high spatial resolution (<1 m) imagery in contrast to other moderate resolution data alternatives (Madarasinghe et al., 2020; Gopalakrishnan et al., 2020).[30] GEP images only contain information from the visible portions of the electromagnetic spectrum (380 – 700 nm), making them limited compared to other satellite images such as Landsat, but the images provide excellent visual information of land use and land cover distribution (Almeer, 2012). This is because GEP gives a "drone eye view" of the landscape using a combination of digital elevation models (DEMs) and high spatial resolution satellite and aerial images, as well as the mosaicking of historical and current images to ensure cloudless scenes (Gopalakrishnan et al., 2020). The collection of GEP historical aerial imagery varies in date of acquisition and resolution depending on the study area. The availability of both medium to high spatial resolution images and time series data makes the program an efficient tool for land use detection and analyzing study area change (Abdelaty, 2016; Warnasuriya et al., 2018).

The high spatial resolution images selected for the land change assessment of the study area were taken at approximately at an altitude of 5000 m (see Figure 8 and 10 for reference). This elevation setting allowed for the best ground truth interpretation of buildings, roads, evaporation ponds, and pumping stations [associated with SDJ mining operations], which cannot be seen at higher altitude settings of the aerial images (e.g., LaJeunesse Connette et al., 2016). Based on the GEP images available with the highest spatial resolution at the desired scale, 2016 and 2020 images were selected for land area change detection. During these years, high spatial resolution imagery enabled a higher degree of accuracy in identifying SDJ mining operations and in the delineation of features using the Add Polygon tool in Google Earth Pro (Lechner et al.,

[30] Resolution determines the maximum display scale. The clearest and most detailed images have a higher resolution (also results in a larger file size, storage space, cost). High resolution images have more pixels per metric, resulting in a crisp photo. The spatial resolution of Google Earth Pro imagery varies by place. Most of Google Earth's imagery resolutions can range from 15 m resolution to 0.15 m resolution (Cha & Park, 2007; Henshaw et al., 2019). For further details about image acquisition, see https://www.maxar.com/products/satellite-imagery.

2019). Since earlier years of the study area do not display mining operations at this scale (see Figure 7), the significance of these years for the stages of the SDJ project was also considered upon the selection of satellite imagery. As discussed by Lechner et al. (2019), each mining project iteration indicates the potential for change from exploration to construction, to operation with cycles of expansion and increased production (see Figure 9 and Figure 11). The changes in the footprint of a mine can have negative social and ecological impacts in the general region depending on the size, nature, and intensity of operations (Lechner et al., 2017).

Two classes were used to identify changes in land use within the study area of SDJ: mining operations and evaporation ponds. The area of the SDJ mining operations (Class 1) were defined as the infrastructure built to support the extraction, processing, production, and exports of lithium mining. Successful lithium mining operations require changes in land cover from the original state to roads, brine pumping stations, offices, processing sites, etc. The existing paved highways that service project operations (RP 70 and RN 52) were not calculated as part of SDJ's mining operations area. The identification of the SDJ operations infrastructure are as they appear in 2016 and are not visible in the earlier GEP time series data. A separate area delineation was calculated for the evaporation ponds (Class 2), given their importance in lithium mining methods and their potential for long-term effects on local aquatic systems due to their water-intensive nature. The total area of evaporation ponds is characterized by the total area of the evaporation ponds and the roads directly surrounding the perimeter of each pond. The expansion of evaporation ponds is defined by the delineation of the empty ponds which were not yet filled (non-operational) as displayed in the 2020 image of the study area. Percentage change in the area between the two years was calculated to assess the land use change for mining operations over time.

**Results and Discussion**

*SDJ's Mining Operations Area Change between 2016 and 2020*

The year 2020 experienced a 34.68% increase in SDJ mining operations area since 2016 (Table 1). Similarly, the SDJ's evaporations pond area increased 66.34% between 2016 and 2020. This change is anticipated due to the expansion announced by Orocobre in 2018 in their efforts to double their production of lithium carbonate.

**Table 1:** Percent change in land use area pertaining to the SDJ mining operations using the highest spatial resolution imagery available in Google Earth Pro's historical record. The areas for each year are measured in square kilometers ($km^2$).

| **Land Use Area** | **2016** | **2020** | **Percent Change in Area** |
|---|---|---|---|
| SDJ Mining Operations Area | 0.5628 | 0.7580 | 34.68% |
| SDJ Evaporation Ponds Area | 5.5015 | 9.1511 | 66.34% |

As visible in Figure 9 and Figure 11, evaporation ponds take the largest amount of area in the total mining operations area and are essential in the lithium mining process after extraction. Table 2 summarizes the area of the expansion of evaporation ponds as identified by the ponds that are non-operational. Moreover, the total area of the existing (filled) evaporation ponds and the expansion area was calculated and compared with the change in areas from both our time series. The SDJ evaporation ponds area (for lithium processing) experienced a 190% increase since the 2016 area and a 74.3% increase in evaporation ponds area since 2020.

**Table 2:** As of 2020, the expansion of the SDJ project evaporation ponds had not been filled. This table summarizes the total area of the additional ponds in addition to the existing ponds and the percent change of the total area compared to the 2016 and 2020 areas. Areas are measured in ($km^2$).

| **Expansion of Evaporation Ponds (Non-Operational)** | **Total Area of Evaporation Ponds Upon Completion (after 2020 data)** | **Percent Change from 2016 Area** | **Percent Change from 2020 Area** |
|---|---|---|---|
| 6.8034 | 15.9544 | 190% | 74.3% |

*The Influence of Teleconnections*

The goal of this quantitative assessment was to identify the change in surface mining operations area extent using publicly available high spatial resolution imagery. As this study demonstrates, mining operations can undergo expansion phases even after the commissioning of a mine. These phases result in large transformations of landscapes to support all aspects of lithium mining operations. In the four-year period of this study, the total area of mining operations, including the area of the non-operational ponds upon completion, increased by 10.65 $km^2$.

In recent years, the intensification of lithium mining activity in Argentina is attributed to national and provincial policy trends and consumption patterns in distal locations. In an earlier section, I discussed the changes in Argentina's natural resource and mining policies which made conditions favorable for foreign investment. Jujuy's provincial government's push for developing its lithium mining industry demonstrates the strong influence of the state in the management of natural resources and transformation of land use for mining projects. In addition to policy shifts in Argentina which has undoubtedly reconfigured the *puna* to become a major site of lithium mining operations, the global demand for lithium (specifically, for lithium-ion batteries) has also accelerated land use conversion for extraction (and other operational) purposes. Recently, many automotive manufacturing companies have announced their plans for new electric vehicle (EV) models and bolstered production (White, 2021; Toyota, 2021; General Motors, n.d.). The capacity of the electric vehicle industry to grow is contingent on the rate of extraction of lithium. Therefore, when a company announces its plans for models of EVs, it is likely to be reflective in the transformation of land where the lithium deposits are located. This is through the expansion of lithium mining operations; thus, land in the *puna* is converted to support these operations through the introduction of infrastructure. Further, the biophysical composition in sites of extraction (and surrounding areas) of the Argentine *puna* is altered because of the water and chemical-intensive lithium extractive practices. As Izquierdo et al. (2018) demonstrates in their study, the limited water availability in the region has also led to a decrease in agricultural and pastoral capacity in the region (a traditional way of life in Olaroz). The increase in the number of mining projects and intensification of extraction in recent years, not only in Argentina but also in Chile and Bolivia, is attributed to the surge in demand for lithium to sustain electric vehicle production and consumption. As the teleconnections approach alludes to, biophysical conditions and reconfiguration of the land are driven by processes distal to the site of lithium extraction.

## LIMITATIONS

In this research, the application of remote sensing has proven as an effective tool for assessing land use change and generated meaningful information about the extent of land use to support SDJ's lithium mining operations. However, the methodology utilized in this study involves a few inherent limitations. The main challenge of this research was the limited data readily available and accessible. Global and country land use and land cover (ex. MODIS) datasets that were available for download were not up to date, meaning they do not accurately illustrate the different stages of the mining operations area. The precision of manual land use classification is highly contingent on the resolution of imagery. The limited publicly available high resolution multi-temporal imagery of the study area at the desired scale affected the years that were selected. Although Google Earth Pro's collection of historical imagery was preferred over Landsat satellite imagery due to its overall higher resolution, image spatial resolution varies across different scales and time. The lack of diversity of land use and land cover types in this area of the Argentine *puna*, resulted in the land use type identification in this study being limited to manual interpretation of SDJ mining operations infrastructure as it appears in the 2016 and 2020 GEP satellite imagery. Secondly, the results of the land use change assessment are limited by my own visual interpretation and manual (freehand) illustrations of the land use classes identified in this study. This potential individual human error must be acknowledged to account for any discrepancies in the areal results if this study were to be repeated using the same methodology. The time frame and scope of the study did not allow for a more in-depth assessment of the drivers of land transformation over a more extended period in the study area. The time constraint also posed a challenge in the addition of methods and acquisition of more data to ensure a higher degree of accuracy of land use classification of SDJ's lithium mining operations area and in identifying the extent of environmental impacts attributed to lithium mining.

The travel restrictions imposed due to the COVID-19 pandemic (when this research was conducted) prevented me from conducting fieldwork and expanding on the qualitative methods utilized in this study. Since I could not conduct in-person interviews or arrange remote interviews (due to the time constraint and other COVID-19 related challenges), I opted to build upon primary and secondary sources that were freely accessible online in English and Spanish. Lastly, due to the timeliness of this topic and the rapid evolvement of the lithium mining industry in Argentina, it is possible that the information used and data gathered in this research will become outdated as more studies on lithium become available. As this thesis demonstrated, the rapidly changing political and economic conditions under which the lithium mining industry is developing make this a very complex topic to assess and limits is comparability to other sites. Therefore, my analysis of the role of the state and the results generated on the biophysical changes attributed to lithium mining is limited to the case of Jujuy's provincial government and the SDJ project.

## CONCLUSION AND FUTURE RESEARCH

From a teleconnections perspective, I broadly analyzed the drivers of changing land patterns in the Argentine *puna* that stem from shifting demands and consumption patterns in distal locations. Land use conversion in the *puna* to support lithium mining operations is accelerated by national and provincial policy trends and the global demand for lithium. My analysis of Jujuy's provincial government support of mining projects through a logic of development and its lack of adequate management of water resources being affected by lithium extractive activity—specifically, in the Olaroz region—suggests that the environmental impacts of lithium mining are not well known or strategically remain ambiguous to the public. This is because lithium mining operations in Jujuy are still primarily controlled by transnational corporations, despite the state's stake in the project. This thesis broadly explored various ways the state as a governing authority and stakeholder justifies the intensification and exploitation of lithium mining as a mode of development through various legal and political frameworks related to mining. Lithium mining can generate social and economic benefits for Jujuy, and it has (ex. employment opportunities). However, the short-term benefits Jujuy's government uses as an incentive strategy to garner public support of expanding its lithium mining sector are accompanied by inevitable ecological consequences.

As the neo-extractivism literature suggests, a "state-led" model of extractivism, while optimistic of social and economic development agendas, still results in very localized environmental damage. Using the Sales de Jujuy project as a case study (one of the two commercially operating projects in Argentina), it was possible to quantify the extent of neo-extractivism (as a driver of change) by identifying land use changes to support lithium mining operations. As this research illustrates, even in the span of four years, land use for lithium mining operations can undergo large area transformations. As the lithium demand continues to rise, we can expect these significant land changes.

The extent of environmental impacts attributed to lithium mining footprints in the Argentine *puna* is an area of research that is largely underexplored (with the exception of: Izquierdo et al., 2018). Although this study focused on the transformation of the biophysical landscape as it related to land use for mining operations, several studies point to the potential negative environmental implications of extracting lithium from brines as the ones found in the *puna* (e.g., Flexer et al., 2018; Liu et al., 2019; Liu & Agusdinata, 2020). As I addressed in an earlier section of this work, this is mainly due to the water and chemical-intensive nature of lithium extractive methods which pose a serious risk to local flora, fauna, and communities living near the mining operations. Without proper monitoring of water usage for lithium mining operations, the extent and severity of environmental impacts related to mining could potentially increase. As this study highlighted, lithium mining operations can expand to considerable degrees to increase production and processing capacity. To mitigate the potential ecological consequences attributed to lithium mining, I repeat the advisement put forth by Flexer et al. (2018), “A serious monitoring program of water levels both under and in the vicinity of the salar by governmental regulation agencies or independent institutions is certainly advised, to settle all current controversies between mining companies and environmentalists.” Since the environmental impacts attributed to lithium mining is the biggest area of contention between local communities, mining companies, and the state, proper monitoring and policing of current environmental regulations will enable more transparency between stakeholders and ensure responsible mining operations.

As this industry continues to grow due to the increasing demand for lithium, I urge future research on the environmental impacts of lithium mining to consider both the human-induced processes and the biophysical processes that cause change on the ground, as I have done in this work. I encourage future work to expand on my qualitative assessment of Jujuy’s laws, statutes, and political conditions and my quantitative methods using remote sensing. In a time when global travel is safe, I recommend fieldwork in Jujuy, Argentina. This would allow the opportunity to interview elected officials and corporate executives to understand their motivations behind expanding lithium mining operations in the province and inquire about regional development efforts. Because lithium extractive activity directly burdens the local scale, it is important to conduct a multi-stakeholder analysis. This means interviewing local communities to listen to their understanding, experiences, and concerns with all aspects of lithium mining operations—most importantly, the environmental impacts.

To improve the accuracy of the quantified biophysical changes and to identify the severity of impacts, alternate remote sensing methodologies can be utilized. For example, this work can be strengthened by increasing the time span of land use change detection and by including high resolution satellite imagery of each year (in the time period) to calculate the rate of change per year. Since I addressed the environmental impacts of lithium mining by generalizing the biophysical configuration of the *puna*, it would be useful to assess the consistency of land change over time to identify any catalysts of change that were not mentioned in this work. Upon the acquisition of up-to-date and reliable land cover data, assessing land use and land cover change over a longer period (than was performed in this study) will allow us to deduce the extent to which lithium mining is the driving factor and further support the need to reconsider common lithium extractive methods. This can also serve as a model for other areas experiencing environmental transformations as a due to lithium extractive activity.

In general, the expansion of lithium mining frontiers is justified in the name of the green energy transition. If a global solution to climate change is at the expense of local communities and biophysical systems, it is perhaps time to rethink this "sustainable" solution.

## APPENDIX


**Figure 1.** This map shows the country of Argentina located in the southern cone of South America.

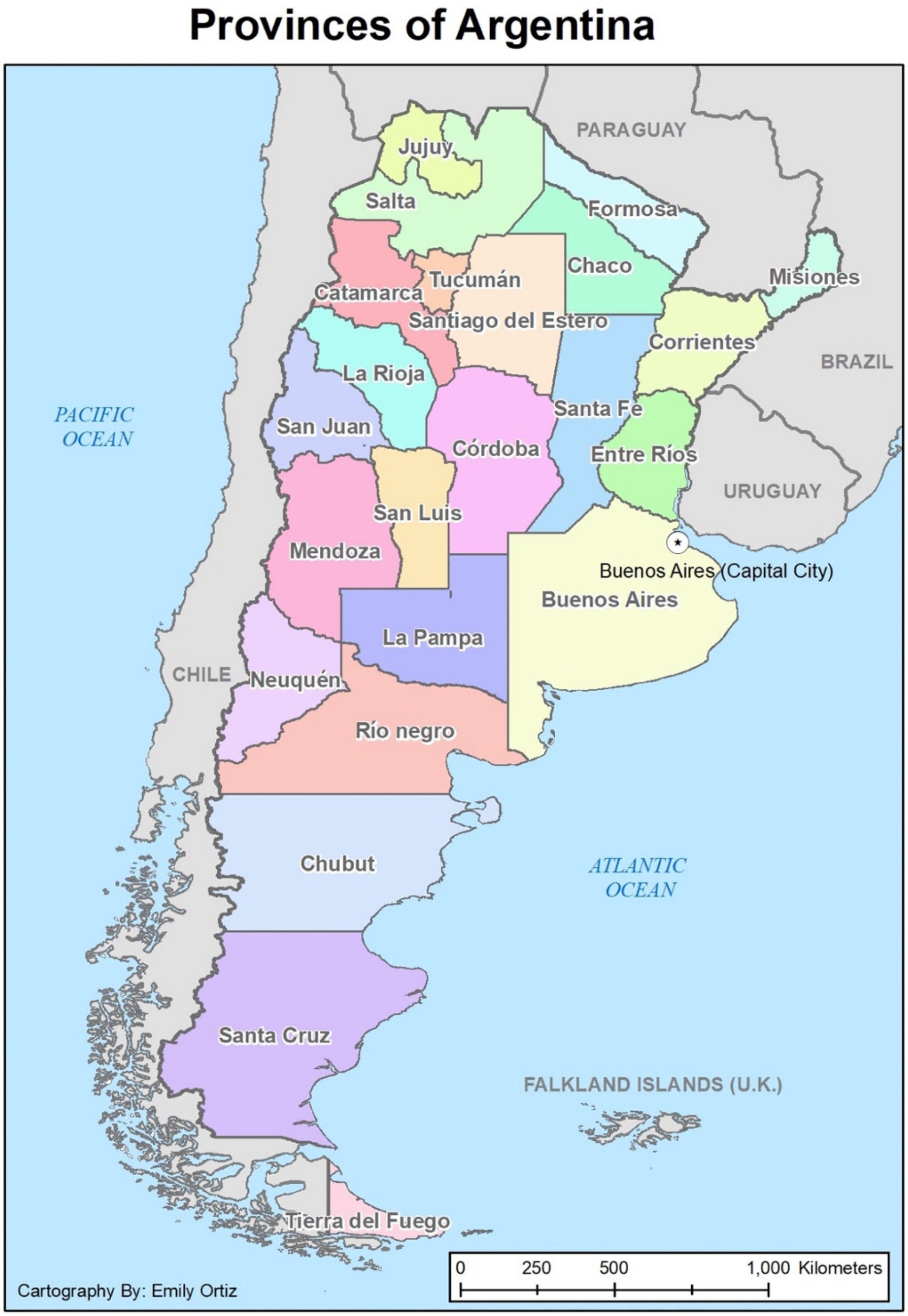


**Figure 2.** This map shows the twenty-three Argentine provinces and the capital (autonomous) city of Buenos Aires. Argentina shapefiles data source can be found here.

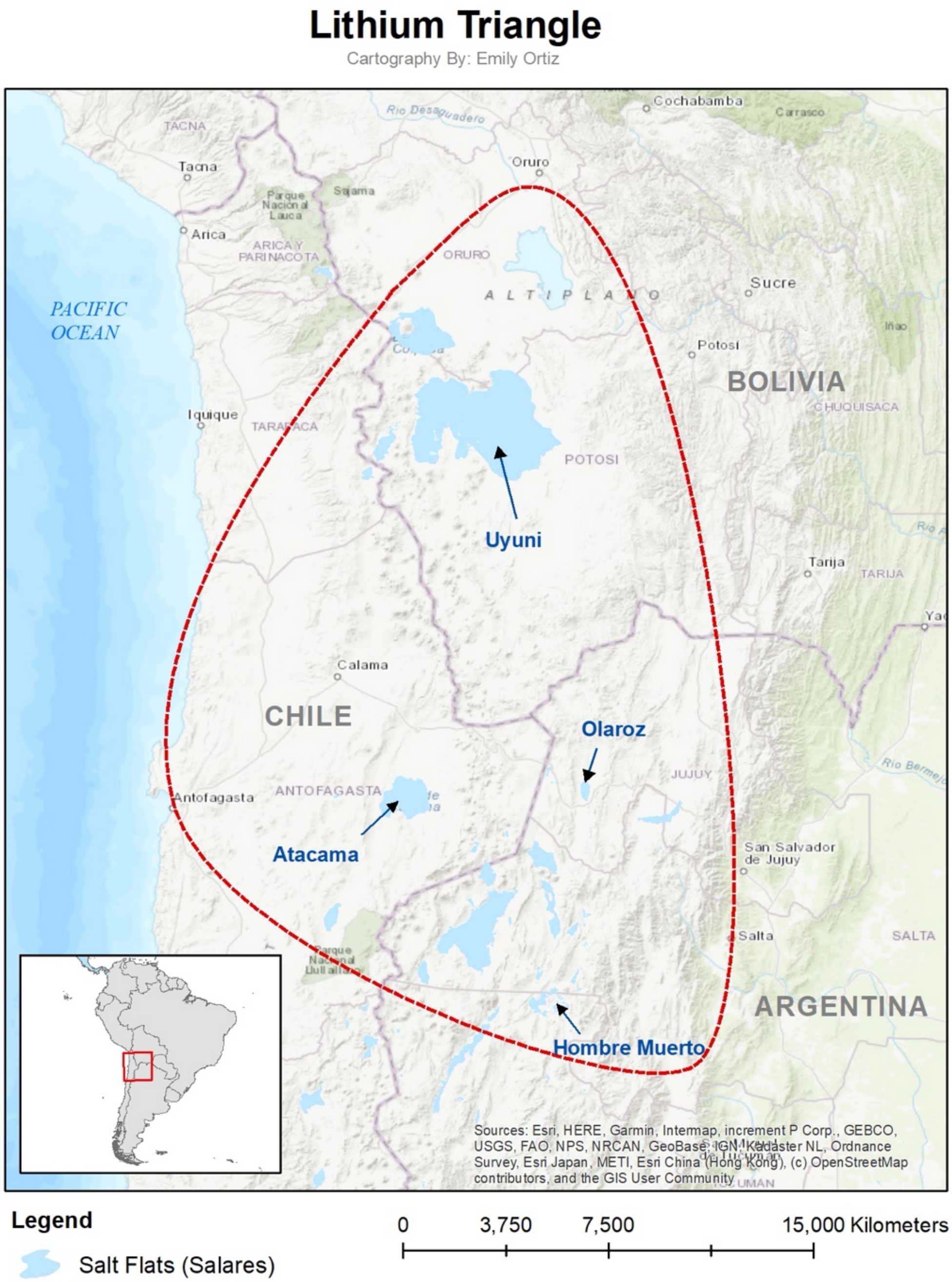


**Figure 3.** This map outlines the parts of Bolivia, Chile, and Argentina that make up the "Lithium Triangle." Data source for salt flats shapefile is ArcGIS online.

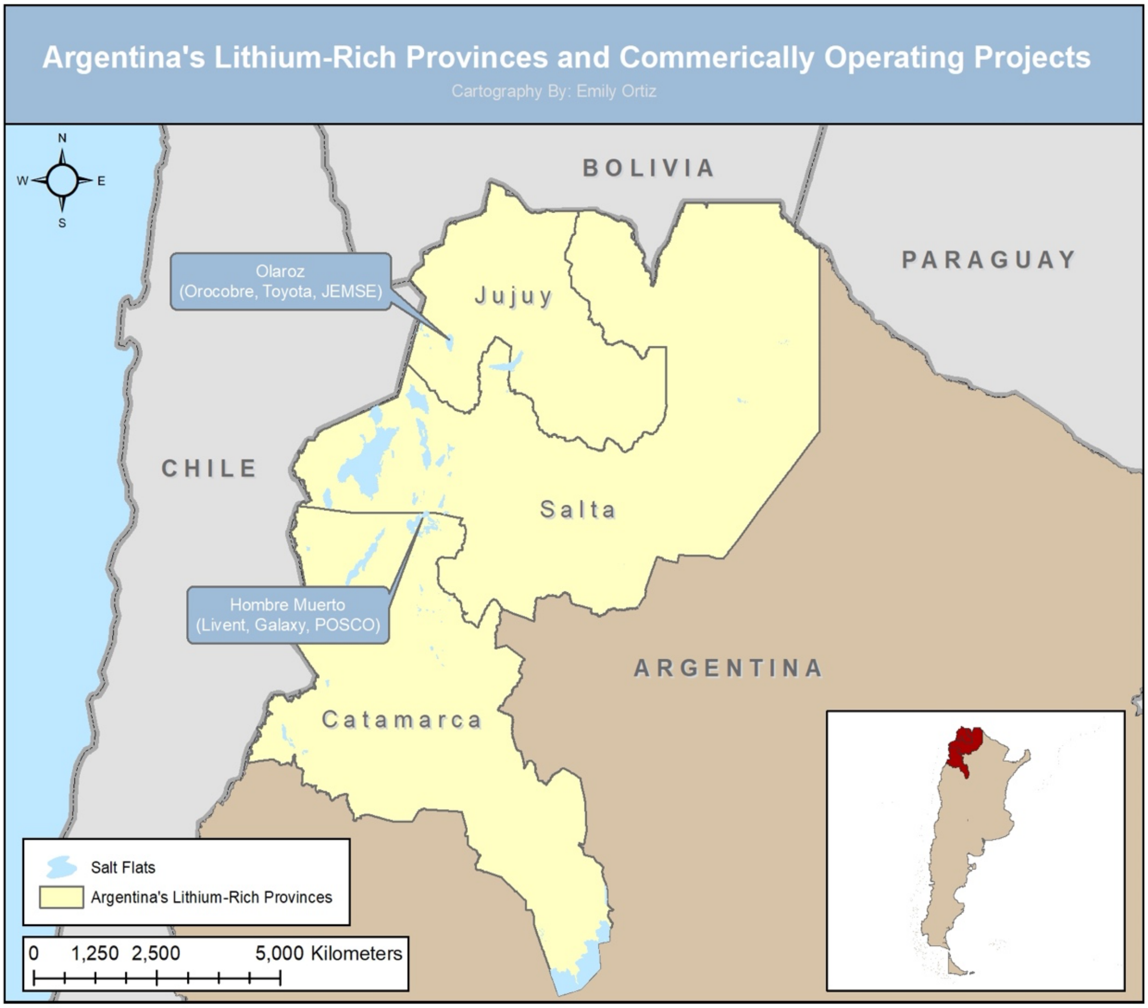


**Figure 4:** This map shows the locations of Argentina's commercially operating lithium mining projects. The companies that own the projects operating in the Olaroz salt flat and Hombre Muerto salt flat are indicated are parenthesis. Data source for salt flats shapefile is [ArcGIS online](#).

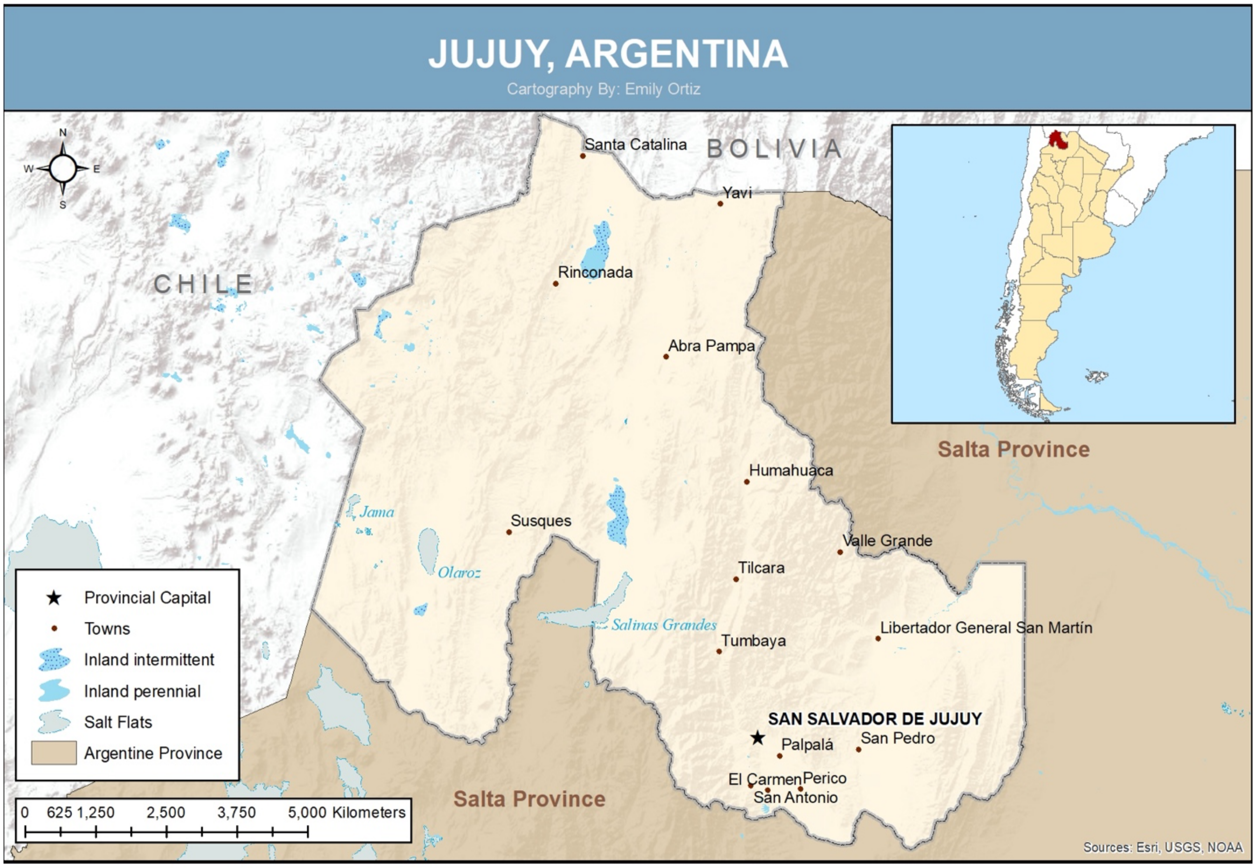


**Figure 5.** This map shows the towns, capital city, and water bodies (including salt flats) in Jujuy, Argentina. Water bodies layer was downloaded from ArcGIS online. Argentina provincial boundaries can be found here.

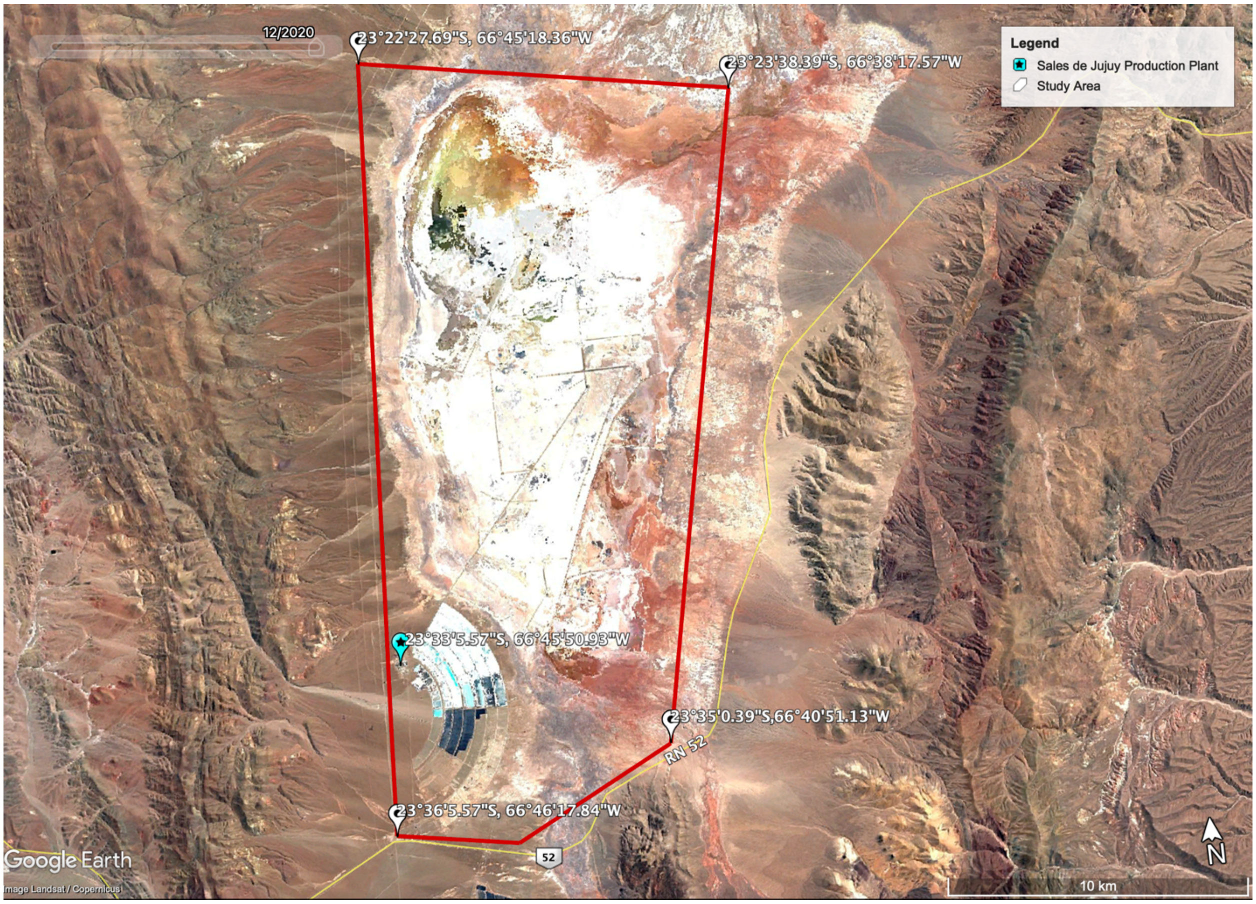


**Figure 6.** This image shows the Sales de Jujuy Project operating area delineated in red. This includes the SDJ production plant and the Olaroz salt flat. Satellite imagery was obtained from Google Earth Pro. Image captured in December 2020.


**Figure 7.** A 2009 image was selected from Google Earth Pro's historical imagery to assess land cover and land use prior to the construction of SDJ mining operations. Reference points of the SDJ production plant location and evaporation ponds are included. Yellow line represents road (RN) 52.


**Figure 8.** This image is from Google Earth Pro's historical time series data which shows the Sales de Jujuy operations site in 2016. This image was captured at an altitude of 5,000 m.

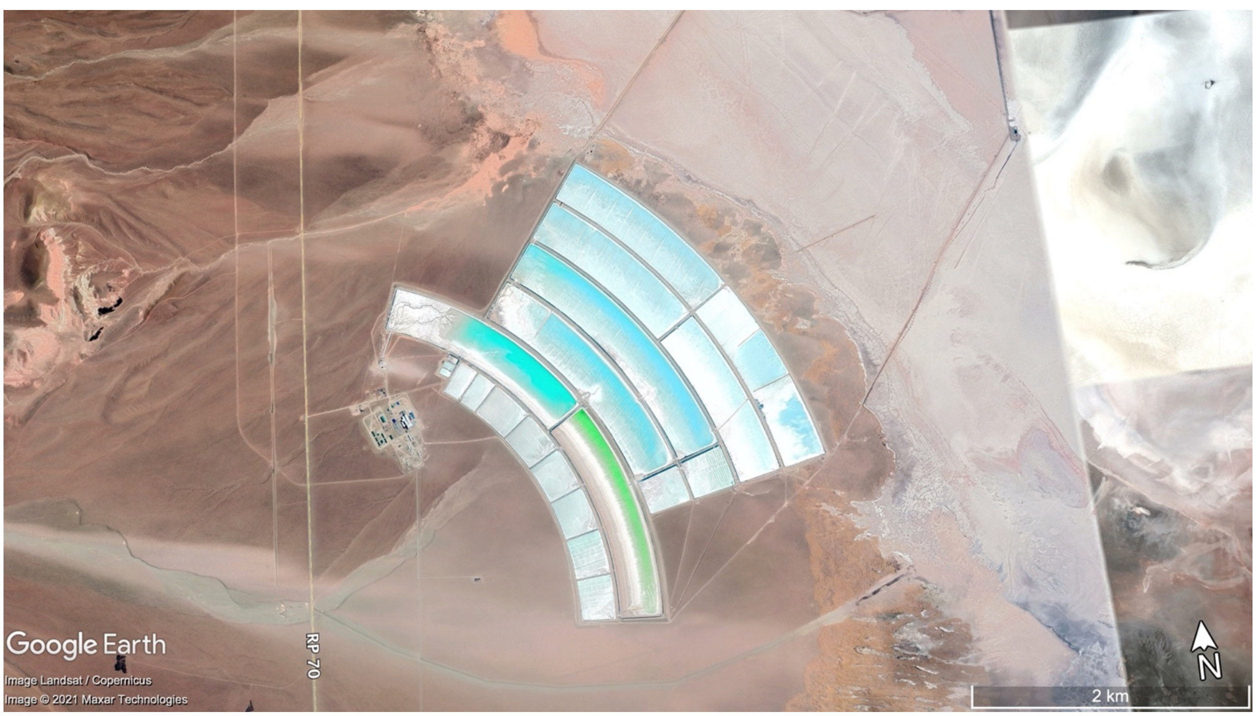


**Figure 9.** This image captures the 2016 SDJ operations area at an altitude of 12,000 m.


**Figure 10.** This image is from Google Earth Pro's historical time series data which shows the Sales de Jujuy operations site in 2020. The image was captured at an altitude of 5,000 m.

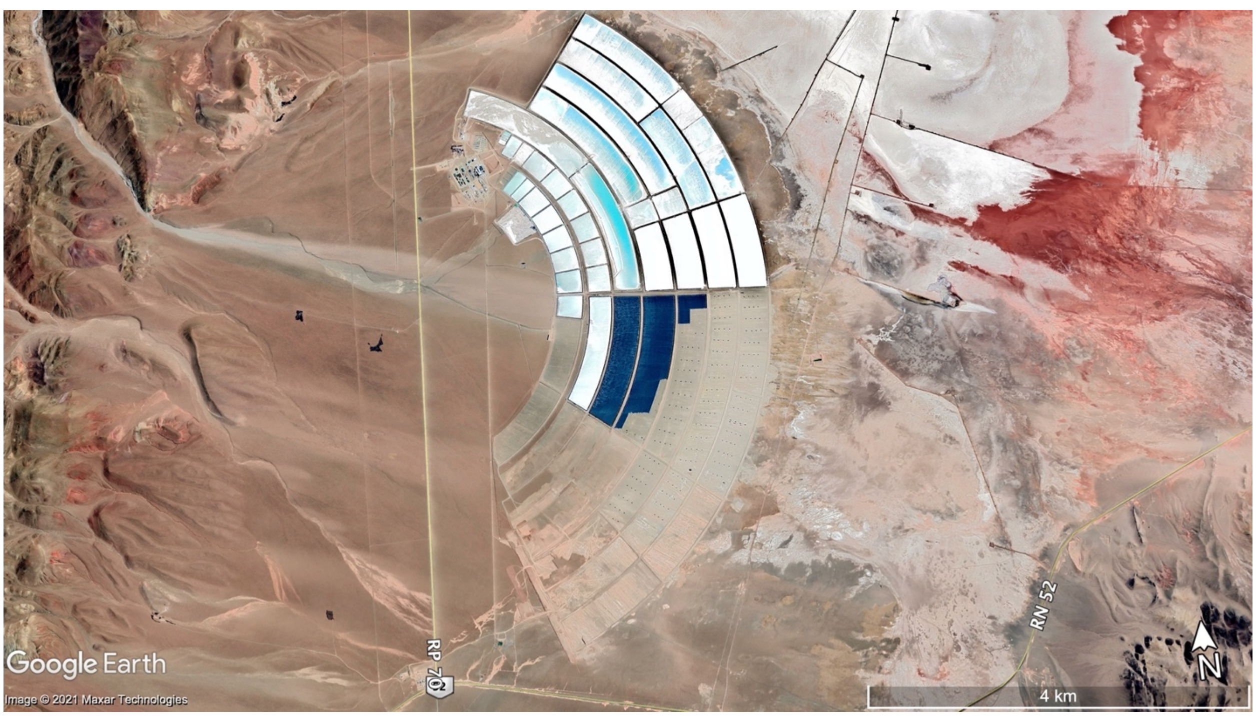


**Figure 11.** This image captures the 2020 SDJ operations area at an altitude of 16,000 m.

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