The Ethical and Environmental Implications of Lithium Mining in the Atacama Region

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Abstract

This research paper aims to critically examine the ethical and environmental impacts of lithium mining in the Atacama region, South America, with special emphasis on the environmental, social, and socioeconomic impacts. As the global demand for lithium skyrockets due to its essential role in the production of electric vehicles and renewable energy storage, the Atacama Region, home to one of the world's largest lithium reserves, has become a focal point of extraction efforts. By reviewing various case studies and reports, the paper will highlight the environmental degradation caused by intensive and wasteful water usage in mining operations which further leads to the depletion of freshwater sources vital to the indigenous peoples and local agriculture. Furthermore, it investigates the role that the socioeconomic divide created by mining companies has as the benefits of operating in this region are often disproportionately skewed in favor of multinational corporations at the expense of local populations and ecosystems. Ethical concerns will be analyzed through a lens of environmental justice and corporate responsibility will be juxtaposed against the criticisms of current mining practices and resource distribution, calling for more regulations and global accountability to ensure that the global transition to clean energy is actually a “clean process” and doesn’t cause further environmental harm at the expense of vulnerable communities and fragile ecosystems.

Keywords: Sustainability, Lithium-Ion, Atacama, Extractive Industries

1. Introduction

Although it is widely believed that electric cars are the future of automotive sustainability, we are all to believe that electric cars are far more sustainable than their internal combustion engine(ICE) counterparts, however the batteries used by those cars, which are lithium-ion batteries, create an extreme amount of pollution, so much so that one can argue that the development of these batteries results in worse pollution than the output of an ICE.The main source of lithium globally, which is the main component of these batteries, is located in the Atacama region i.e. Peru and Chile. The way in which lithium is being mined in these regions, however, completely destroys the natural environment. A study from The Wall Street Journal in 2019 revealed that 40% of the total climate impact caused by the production of lithium-ion batteries comes from the mining process itself. This obviously, should lead us to believe that there should be a severe modification in the process of mining, specifically toward a more sustainable form of lithium mining, like the one suggested by the “Sustainable Review” organization, which states that “One such method is extracting lithium directly from hard rock ore deposits using innovative technologies like direct lithium extraction (DLE)” It is clear through multiple studies that have been conducted that the mining process of lithium requires a severe modification and change in direction to a more sustainable focused path.

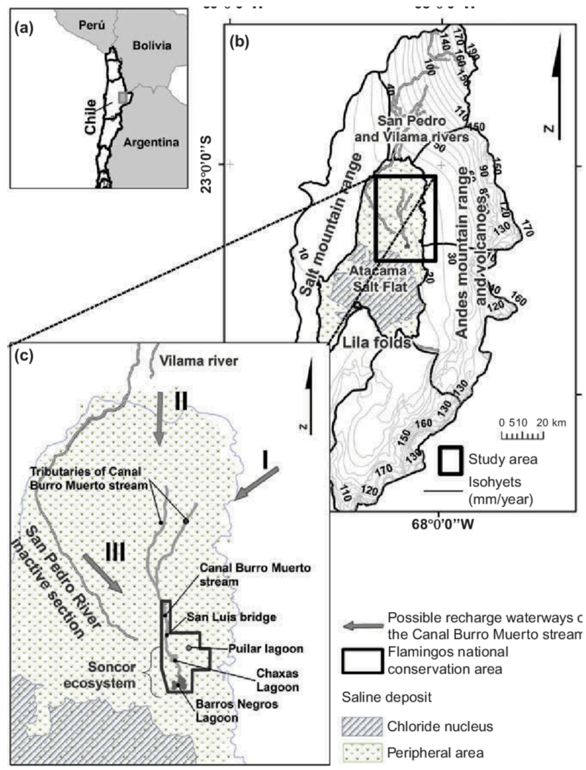
One of the largest problems with lithium mining processes is brine evaporation. Traditionally, brine water lithium has been collected via evaporation. Through a series of treatments and processing, lithium is removed from the brine water by pumping it from the salar, or salt flat, into vast ponds where evaporation can occur and create heaps of salt. While this method has sufficed up to this point, it has also brought problematic issues with it. The fact that it takes a while for the water to truly evaporate is the first problem with the evaporation process. The time-to-market for this production method could be prolonged because it often takes a year or longer for the water to entirely evaporate. In addition, building the operations facility must be completed before the water can even be pumped. The second problem with the evaporation method is that by leaving heaps of salt as residues it is infamous for ruining the salar's natural ecology. Furthermore, the neighboring residents who depend on this source of water now have to find alternative supplies of water in an already limited environment because the saline water that is pumped from the earth has evaporated into thin air. The processing and rigorous chemical treatments that the salar salts must undergo in order to yield commercial-grade lithium are the next problems with the evaporation method. Chemical waste from the lithium purification process typically ends up in ponds, where it eventually seeps into the earth and contaminates nearby rivers and other bodies of water.

According to a report by Friends of the Earth (FoE), lithium extraction inevitably harms the soil and causes air contamination. As demand rises, the mining impacts are “increasingly affecting communities where this harmful extraction takes place, jeopardizing their access to water,” says the report. The salt flats in South America where lithium is found are located in arid territories. In these places, access to water is key for the local communities and their livelihoods, as well as the local flora and fauna.

In Chile’s Atacama salt flats, mining consumes, contaminates and diverts scarce water resources away from local communities. As a result of the extraction process in the salt flat, millions of tons of water are removed from the system in arid regions, the biota is affected, and natural conditions change in this fragile and dynamic ecosystem. The impact on the salt flat not only translates into loss of water, but also in the disappearance of vulnerable species that only exist in these places, the loss of the cultural heritage of indigenous peoples, the millions of years of evolution of adaptation processes of species, including extremophilic organisms. From economic point of view, although both companies are committed to compensating the damage to the Atacameñas communities, one with 3.5% of the value of sales and the other with a contribution of US$15 million annually, it is not comparable with the deterioration of the Salar and the loss of cultural heritage. According to Dr. Ingrid Garcés, a professor of chemical engineering at the University of Antofagasta, around 2 million liters of water evaporate for every ton of lithium produced. Atacameño/Lickanantay and other Indigenous Peoples have developed agro-pastoral and irrigation practices suitable to the extremely arid environment, cultivating crops and raising livestock based on local knowledge. The rapid expansion of lithium after decades of intensive copper mining is depleting their groundwater resources. This is being done with uneven and improper consultation or consent under the principles of the International Labor Organization Convention 169 or the United Nations Declaration on the Rights of Indigenous Peoples.

The Puna de Atacama is also home to protected wetlands and extraordinary wildlife. The area’s lagoon oases host three species of flamingos, as well as endemic animals and unique microorganisms at risk of extinction. Lithium mining has already been shown to reduce the local populations of two of these three species of flamingos in the Atacama salt flat, and scientists suggest the impacts could grow more widespread as lithium mining expands.“As of 2022, worldwide, there are eight full-scale active facilities that produce lithium compounds from continental brines9 and more are likely to become active before 2030 (Fig. 1a). The evaporitic technology (Fig. 1b) is currently in use at seven of those facilities 18,19. Brines are pumped from underground reservoirs into open-air ponds, in which over 90% of the original water content is lost through evaporation. Concentrated brines are then transferred to a refining plant for removal of impurities, followed by Li2CO3 precipitation via the addition of Na2CO3. Fresh water is needed at multiple steps of the process, including to dissolve CaO (needed to precipitate Mg2+) and Na2CO3, in the scrubbing of organic solvents (used for the removal of borates), for washing Li2CO3 crystals and for steam generation Over 90% of the salts other than LiCl in the original brines spontaneously crystallize in the ponds and are considered waste.” (Vera, María L., et al. “Environmental Impact of Direct Lithium Extraction from Brines.” Nature News, Nature Publishing Group, 23 Feb. 2023). “Evaporitic technology for lithium mining from brines has been questioned for its intensive water use, protracted duration and exclusive application to continental brines. In this Review, we analyze the environmental impacts of evaporitic and alternative technologies, collectively known as direct lithium extraction (DLE), for lithium mining, focusing on requirements for fresh water, chemicals, energy consumption and waste generation, including spent brines. DLE technologies aim to tackle the environmental and techno-economic shortcomings of current practice by avoiding brine evaporation. A selection of DLE technologies has achieved Li + recovery above 95%, Li + /Mg 2+ separation above 100, and zero chemical approaches. Conversely, only 30% of DLE test experiments were performed on real brines, and thus the effect of multivalent ions or large Na + /Li + concentration differences on performance indicators is often not evaluated. Some DLE technologies involve brine pH changes or brine heating up to 80 o C for improved Li + recovery, which require energy, fresh water and chemicals that must be considered during environmental impact assessments. Future research should focus on performing tests on real brines and achieving competitiveness in several performance indicators simultaneously. The environmental impact of DLE should be assessed from brine pumping to the production of the pure solid lithium product. Sections.

With a few exceptions, the salinities of these peculiar waters are five to ten times higher than those of saltwater (Bowen and Benison, 2009). These investigations also show that the fluids are brines of Na+Cl and Na+Mg+Cl+SO4, most of which have a pH of less than 4. These brines have developed as a result of intense weathering and evaporation, but their Li content is rather modest. The bulk of brines contain less than 0.5 mg/L Li, with only one brine sample above 1 mg/L (B. Bowen, pers. commun.). These systems' climate and hydrology are ideal for enriching Li, but it is obvious that there isn't a strong enough Li source or concentrating mechanism in place. (Munk and Ann, 2016)



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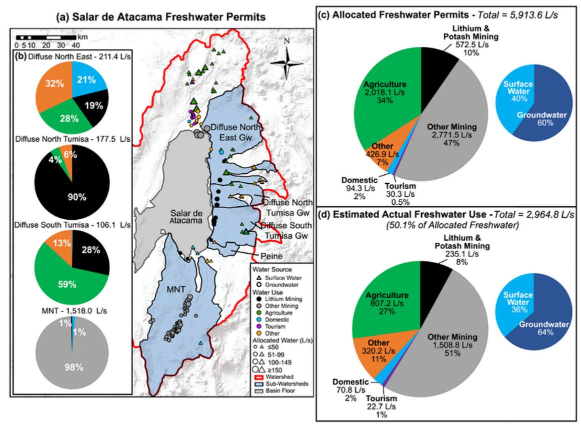
Part A: Socioeconomic Dynamics

In this section, I will illustrate with the help of two salt flats in the Atacama what happens when a large number of people come to depend socioeconomically on the lithium mining industry, and then, due to adverse effects, their standard of living continues to debilitate to highly unsustainable levels. A global shift to renewable energy is becoming more urgent due to the climate problem, and governments and industry, particularly in China, Europe, and North America, are fighting for a consistent supply of lithium for energy storage technology. The borders between Argentina, Bolivia, and Chile contain some of the world's largest lithium resources. Here, businesses collect the metal by draining brine from beneath the area's salt flats and allowing the water to evaporate in enormous ponds. Particularly significant is the Atacama Salt Flat, or Salar de Atacama (SdA), in Chile, which presently provides 84% of the lithium used in Europe and 40% of the USA (USGS, 2020; WITS, 2021). Albemarle Corporation and SQM (Sociedad Química y Minera de Chile) have been mining lithium there for more than 20 years. Recent years have seen a sharp increase in extraction because of rising worldwide demand. The Atacama Desert became a center of national development as a result of the expanding market for saltpeter, which was once utilized as fertilizer in Europe. This contributed to Chile's economic integration with the world. Water, land, and resources were taken away from politically vulnerable Indigenous communities and turned into state property. The state then gave concessions to the mining sector (Acuña and Tironi, 2021; Morales and Azócar, 2015). It also produced a tangle of conventional and commercial methods. Regional marketplaces were incorporated with indigenous economies. An increasing number of Indigenous peoples started working as unskilled laborers in mining operations at this time. After 1915, copper overtook saltpeter in terms of relative importance. Copper mining is still important because of Chuquicamata and La Escondida, two of the largest copper mines in the world, both located in the Atacama region respectively. But it has had a significant impact on the area, leading to a serious water scarcity and changing the perception of Indigenous peoples from "primitive" residents of an unincorporated borderland to common unskilled laborers in the mining industry. When the firm that would run Chuquicamata researched the SdA in 1962 in search of water for its operation, that is when the earliest reports of the existence of lithium d (Pavlovic, 2014). The initial feasibility studies and prospecting activities for the SdA were headed by CORFO, the state agency responsible for fostering economic growth, in 1975. In the ensuing ten years, Sociedad Chilena de Litio (SCL) and Sociedad Minera Salar de Atacama S.A. (MINSAL) were established as lithium mining companies. In 1984, SCL, a joint venture between CORFO and the American corporation Foote Minerals, started producing lithium carbonate. CORFO sold its interests to Foote Minerals in 1989, a few years later. Foote Minerals eventually partnered with German company Chemetall in 1998. The American business Rockwood Holdings Inc. purchased Chemetall in 2004, and SCL changed its name to Rockwood Lithium Ltd. in 2012. (CORFO, 2016). In summary, the state has steadily withdrawn its involvement in lithium production over the past 50 years in favor of total private capital management. The surface area of lithium mining operations in the SdA has quadrupled from 20.54 km2 in 1997 to 80.53 km2 in 2017, a remarkable growth over the previous 20 years (Liu et al., 2019). Water use in the Salar exceeds supply, with a deficit of 15 m3/s in 2016 (CEPAL-OCDE), and the resulting socio-environmental tensions have been greatly accelerated by the intensive use of water by mining projects, and in particular by the pumping and evaporation of brine in the lithium mines (Babidge et al., 2019; Liu and Agusdinata, 2020).



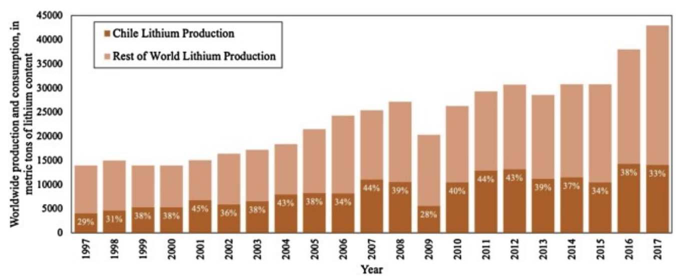
(source 18)

Environmental concerns about lithium mining from continental brines have been brought up by locals, non-governmental organizations, and the media since the early 2000s. These issues were first voiced in Chile, where activities had begun ten years earlier, and later in Argentina. All of the nearby communities are rural, and there is scant documentation on the environmental conditions. Remarkably, energy consumption and carbon emissions have been measured in environmental life-cycle analyses of lithium brine mining, but the effects on the water cycle and particular land uses have been ignored. It was not until 2018 that reliable quantitative data about the detrimental effects of lithium mining on the environment was published. With the exception of Clayton Valley, which has a far lower production capacity, Salar de Atacama was the first salar to be mined. The data, however, are still quite restricted. Brine and fresh water are two separate aquifers that are mined in brine mining and have the ability to physically interact.

There is some debate as to if these water amounts should be taken into account when figuring out the process's hydrogeological footprint. While it is obvious that the freshwater volume needs to be taken into account, it is more difficult to determine the brine volume that needs to be taken into account in the water footprint. Prominent proponents of mining argue that brine should be totally ignored when calculating water footprints. However, In this paper, I that brine is extremely import in the calculation of hydrogeological footprints as the amount of freshwater that naturally flows from outside the brine aquifer (Box 1), mixes with brine, and is subsequently no longer regarded fresh water or suitable for use as such will be directly determined by the volume of brine pumped. When mining is not occurring or when brine pumping is taking place, a variable amount of fresh water flows or moves towards the salar. Salars are a hydrogeological case study because they are harvested from subterranean aquifers to provide both fresh water and brine (Vera et al.). Without hydrological data, it is challenging to determine whether excessive water extraction is taking place, and sadly, hydrological records in the Lithium Triangle are either nonexistent or insufficient.

A decline in stream flow or lagoon area, for instance, is a clear sign of water scarcity and therefore shows an impact on the environment in the atacama region as a direct result of the lithium mining.(Flexer, V., Baspineiro, C. F. & Galli, C. I.) (Agusdinata, D. B., Liu, W., Eakin, H. & Romero, H.) (Liu, W. & Agusdinata, D. B.) The surface area of lagoons on Salar de Atacama has decreased by half in the period 1985–2020 in winter but not in summer (Gutierrez, J. S. et al.) As far as we are aware, there isn't any additional quantitative data on surface water patterns for the Lithium Triangle. On the other hand, it is critical to take into account the decline in subsurface freshwater and brine reserves. According to satellite data, Salar de Atacama's total water storage dropped by -1.16 mm annually between 2010 and 2017, while the average annual loss in soil moisture indexes was -0.005 between 1997 and 2017. From pre-extraction to the present, direct observation wells revealed a sharp decline in the water table (1986–2015).(Marazuela, M. A., Vázquez-Suñé, E., Ayora, C. & García-Gil, A). Water table drops of up to 9 m have been observed in the area where brine wells are located between 1990 and 2015. Thus far, these reductions appear to be restricted to the salar's core and do not appear to extend to the salar's edges or the areas where saltwater and freshwater interact.

Phreatic evaporation, a naturally occurring type of evapotranspiration that happens in salars even in the absence of brine pumping, is another factor to take into account when evaluating subterranean water reserves. There have been conflicting reports of Salar de Atacama evapotranspiration.(Vera et al. 2023) Two studies using satellite data revealed that the phreatic evaporation rate for the salar and nearby areas did not change between 2000 and 2017 , while the other study found a 6% drop between 1960 and 2020. (Gutierrez, J. S. et al.) A third research that combined hydrogeological modeling and field data calculated an average 15% reduction in the evapotranspiration rate throughout the entire salar area since brine mining began in 1994. (Marazuela, M. A., Vázquez-Suñé, E., Ayora, C. & García-Gil, A). Variations in the flora and fauna might also suggest a drop in water levels. Because of the size of the wetlands they occupy, flamingos may be a good indicator of environmental harm. In the Salar de Atacama, a reduction of 10% and 12% has been reported in the populations of James and Andean flamingos, respectively, which is linked to the reduction of surface water, particularly in winter (Gutierrez, J. S. et al.) Therefore, the combination of multiple factors such as water scarcity, flora and fauna abundance, and evapotranspiration show the effect of lithium mining on a specific area, the findings of which may be applicable to the rest of the mines in the region as well.



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Part B: Alternatives and the Way Ahead

Despite the arguments made above in the paper, it is worth noting that lithium mining is still essential today and a sustainable solution to the effects of lithium mining cannot simply be to stop the mining process altogether as the world still requires lithium in abundant sources today. Particularly in light of the worldwide movement toward renewable energy sources and electric vehicles (EVs), lithium is an essential component of many technologies that are essential to modern civilization. Due to its use in rechargeable lithium-ion batteries, which power EVs as well as a variety of portable electronic gadgets including laptops, tablets, and smartphones, lithium is in high demand. Lithium's adaptability has inevitably resulted in an enormous increase in demand. Less than 30% of lithium demand was met by batteries in 2015; the majority of lithium demand was for glass, ceramics, and grease. (Mckinsey) But by 2030, batteries will supply 95% of the lithium needed, according to a recent McKinsey research, with the overall demand rising by 25% to 26% every year. Rather than finding ways to eliminate the process of obtaining lithium altogether, the emphasis should be on improving the environmental and social responsibility of lithium mining. This involves making research and development investments to enhance mining methods, cut back on water use, and lessen habitat harm. Furthermore, in order to recover lithium and other precious elements and lessen the need for new mining operations, it is imperative to develop efficient recycling techniques for lithium-ion batteries. Therefore, in this section, I will provide certain theoretical and policy-oriented points of entry, if not a comprehensive blueprint, into developing a more sustainable method of mining lithium.

Direct lithium extraction has been touted as a more environmentally friendly way to mine the lithium needed for EV batteries. As previously established, lithium is a highly reactive alkali metal with great heat and electrical conductivity, making it perfect for a variety of applications like energy storage and electric vehicles. However, pure elemental lithium is not found in nature due to its high reactivity; instead, it is present as a component of salts and other compounds. Direct Lithium Extraction, or DLE, is a method that comprises multiple chemical reactions that enable quick separation of lithium and conversion of that lithium into forms that may be sold. There are three primary ways to accomplish this: Adsorption: the process of selectively removing lithium by physically adhering sorbents to the material. Following the loading of the sorbent with lithium chloride, undesired ions are eliminated by washing it twice with a stream of diluted lithium chloride, which releases the loaded lithium chloride. Lithium aluminum layered double hydroxide chloride sorbent, or LDH, is the most recent sorbent under test. This approach is ultimately more environmentally friendly because it doesn't call for an acid wash or other chemicals, as detailed in a recent article published in Environmental Science & Technology.Ion Exchange: By replacing unwanted ions with other ions that have the same electrical charge, these systems use a physicochemical process to remove ionic pollutants from solution. As with other lithium extraction techniques, lithium recovery via ion exchange can be altered by making small adjustments to pH, temperature, or stream composition. However, scientists also estimate that this approach can recover about 90% of the lithium that is present. And Solvent extraction which is the process of extracting lithium from brine by either chemical or physical means and converting it into LiCl or Li*.(Jurado et al. 2023)

DLE was created recently in an effort to lessen the drawbacks of traditional methods for obtaining lithium. There are currently two main sources of commercial lithium: mineral ore deposits and subterranean brine deposits. Lithium can be extracted for the former from brine pools beneath salt flats, or salars, the majority of which are found in South America (Bolivia, Chile, and Argentina). Conversely, depending on the particular mineral deposit in question, different methods may be used to recover lithium from mineral ore. Generally speaking, the procedure comprises of extracting the mineral material from the earth, heating it, and then crushing it. Australia uses this method for manufacturing the most lithium that has been produced to date. ((Fernández Jurado, Mora. Darcy Partners). There are a multitude of key benefits to DLE over brine extraction.

In comparison to conventional lithium extraction, DLE offers advantages in terms of speed, yields, and sustainability, according to Summit's vice-president of strategy and corporate development, Adam Le Dain. Such technology is required, he said, as the world's need for lithium to make lithium-ion batteries for electric vehicles (EVs) and energy storage grows.Le Dain and other DLE businesses contend that the process is better than lithium evaporation. Time is a significant distinction. Le Dain stated that whilst DLE takes about a day to create viable lithium, evaporation ponds take eighteen months to yield lithium. Lithium extraction using conventional methods "cannot keep pace with today's rising demands." Lithium production in traditional evaporation ponds can take up to 18 months, whereas DLE can do this in a matter of days. Meeting the growing demand for lithium, particularly for electric vehicle batteries, would require this quick processing (SustainableBiz Canada; FT Markets). Compared to the 40–65% recovery rates typical in evaporation ponds, DLE boasts higher lithium recovery rates, frequently surpassing 90%. Because of its efficiency, more lithium may be recovered from the same volume of brine, maximizing the use of available resources (SustainableBiz Canada, FT Markets).

Additionally, and the basis of the main point of this paper, DLE is advantageous for the environment. It uses less land and water than conventional techniques. Large regions and a lot of water are needed for evaporation ponds, which can harm ecosystems and deplete nearby water supplies. In contrast, DLE reduces its environmental impact through the use of cutting-edge materials and procedures (SEPLite; Sustainable Business Canada). "DLE can be deployed more flexibly and on a smaller scale compared to large evaporation ponds. This adaptability allows for lithium extraction in various geographic and climatic conditions, making it feasible for use in different regions and brine types" (SEPLite) (FT Markets). Finally, Higher purity and more constant lithium outputs are produced using DLE. This is essential for making lithium suitable for batteries which need to meet strict quality requirements. Compared to conventional techniques, the technology's capacity to extract lithium ions selectively guarantees that the finished product satisfies these requirements more consistently (SEPLite; Sustainable Business Canada).

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[20] Author links open overlay panelWenjuan Liu a, a, b, Highlights•Five indicators are examined for the environmental health of the Atacama Salt Flat.•Moderately and highly degraded areas are located.•Areas impacted includes salt flats, AbstractEmerging electric-vehicle technologies and the global transition to renewable energy have driven the production of lithium batteries significantly in the past ten years. However, Artis, D. A., Carter, G., Chen, X., Fan, C., Flexer, V., Gössling, S., Ishtiaque, A., Kampf, S., Li, Z., Marazuela, M. A., Camacho, F. M., Mu, Q., Pettorelli, N., Stamp, A., … Estoque, R. (2019, April 29). Spatiotemporal patterns of lithium mining and environmental degradation in the Atacama salt flat, Chile. International Journal of Applied Earth Observation and Geoinformation. https://www.sciencedirect.com/science/article/abs/pii/S0303243419300996

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