Energy Research & Social Science xxx (xxxx) 103264

Contents lists available at ScienceDirect

Energy Research & Social Science

journal homepage: www.elsevier.com/locate/erss

Original research article

Advancing recognition justice in telecoupled critical mineral supply chains: The promise of social media

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ARTICLE INFO

Keywords:
Social media
Low-carbon technologies
Critical minerals
Telecoupling
Recognition justice

ABSTRACT

Electric vehicles and other low-carbon technologies are increasingly scrutinized for the injustices they impose on critical-mineral mining communities. Injustices arise because local communities that are disproportionately affected by mining are materially and cognitively distant to those who hold influence over supply chain practices, policies, and institutions. The outcome is that these communities lack recognition by producers and consumers who benefit from critical mineral extractions. We focus on the promise of social media as a means to assist distant local communities gain recognition as important stakeholders and as a vehicle for informing mineral-consuming public. Using a case study of the impacts of lithium extraction in Chile, we analyze social media (Twitter) to establish evidence of the telecoupled information flows for communicating the nature of impacts of lithium extraction and the potential for advancing recognition justice. Our findings offer initial evidence of the potential role of social media as a mechanism to: (1) improve the flow of information and knowledge from mineral mining sites into social networks, (2) give voice to local stakeholders who otherwise are not heard, (3) enhance recognition justice for these distal communities.

1. Introduction

The increased production of low-carbon technologies to address climate change has led to greater demand for critical minerals because they are essential to the production of electric vehicles (EVs), storage batteries, wind turbines, fuel cells, and solar photovoltaic panels [1,2]. However, the rising demand for these minerals has also brought concerns about their social and environmental impacts related to child labor [3], degradation of freshwater and marine ecosystems [4], and destruction to indigenous cultural heritage [5]. Addressing such externalities of energy transition requires improved public engagement and governance [6]. Industry efforts to address these harms have been criticized as being public-relation exercises rather than serious efforts to improve governance [7]. Because the local communities that are affected by critical mineral mining activities are typically distant geographically from where the final products are consumed, community voices are not heard, and the negative ecological impacts of mining and their effects on populations and places may be ignored. Social media is one relatively unexplored pathway that holds promise to amplify these voices and concerns.

Social media has the ability to enhance the flow of information across geographies, potentially serving to elevate justice concerns associated with these distal communities, thus motivating more sustainable governance [8]. We assess this potential through the lens of "telecoupling," which argues that social-ecological interactions in distal locations can be "coupled" through material and non-material flows [9–11]. A telecoupling lens can bring focus to the role of information in connecting distal sites of production and consumption.

Previous telecoupling research has identified online news media (more generally) as one potential vehicle of knowledge flows in telecoupled systems [12,13]. Other research shows that in socially and environmentally sensitive industries, such as mining, web-based platforms can be used effectively to communicate sustainability impacts by enabling timely engagement with stakeholders to complement accounting and reporting of impacts [14].

However, to our knowledge, no prior studies have assessed how social media may enhance information flows across telecoupled systems by conveying and amplifying knowledge about the impacts of mineral extractions. In this way, social media can address the challenge of asymmetrical information among local communities most affected by

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https://doi.org/10.1016/j.erss.2023.103264
Received 10 February 2023; Received in revised form 16 August 2023; Accepted 23 August 2023
2214-6296/

critical mineral mining, producers, and consumers, and among the diversity of stakeholders across distal supply chain activities. Supply chains are embedded in power relations, structured by institutional arrangements, finance and capital, and power over discourse and narrative [15]. Critically, social media attention can serve to spotlight otherwise neglected or overlooked implications of consumption, providing opportunities to enhance recognition justice, or justice principles associated with the understanding and acknowledgment of social difference by those actors and organizations in positions of influence and power, and by society at large [16].

This research assesses the promise of social media as a vehicle to deliver information about environmental and social harms, thus acting as a tool to advance recognition justice for the populations and places subject to these harms. More specifically, we ask: *how does social media discuss the impacts of mining activities, which actors are involved in this social media communication about mining impacts, and how are these actors interconnected geographically? How do these results inform our understanding about the role of social media as a means to telecouple distal local communities by delivering information about environmental and social harms?* We explore these issues by focusing on how social media was used to disseminate information about lithium extractions in Chile, which supplies about 38 % of worldwide lithium production. We assess Twitter communication specifically related to the very water-intensive mining activities in Salar de Atacama, which is one of the driest places on earth [17]. We also evaluate communications related to environmental quality degradation in the area and how it is affecting the livelihoods of local communities and the ecosystems on which they depend [18–20].

Our results show that social media provides a vehicle for influential local actors to communicate information about the negative sustainability impacts of mining, thus creating opportunities to reduce misrecognition. Additionally, these actors are embedded in networks that can potentially amplify messages across geographical boundaries. Combined, our findings suggest that social media may serve as an important tool to facilitate the flow of valuable information associated with harms across telecoupled systems, giving voice to distal communities, thus enhancing opportunities for recognition justice in critical mineral supply chains.

2. Environmental justice, telecoupling, and social media

Telecoupling refers to ways in which distal social-ecological-technical systems are connected in complex causal networks of influence and feedbacks, ultimately affecting the prospects of governance of the entire system of drivers and outcomes for sustainability [8,9,11] (see Fig. 1). These distal connections are often triggered by shifts in consumer demand or policy change in a "sending system." In the case of critical minerals, consumer demand is located in the Global North, where the demand for EVs is accelerating. This demand is incentivizing distal resource exploitation in "receiving systems." In our case, resource exploitation is occurring largely in the Global South, which is the system that receives the signal of that demand and is consequently transformed [9]. These shifts in consumer demand are amplified by the social and physical geography of specific supply chain configurations [9,21].

Telecoupling framework helps conceptualize and analyze material (e.g., goods, people, finance, biological/physical elements) and immaterial (e.g., values, information, knowledge, discourse) among distal local communities and ecosystems and globally interconnected supply chain organizations and actors. Telecoupling also serves to focus on the mechanisms through which such flows of information result in changes in system governance [8,22]. The distal connectivity and causal linkages between consumption activities and production processes is one

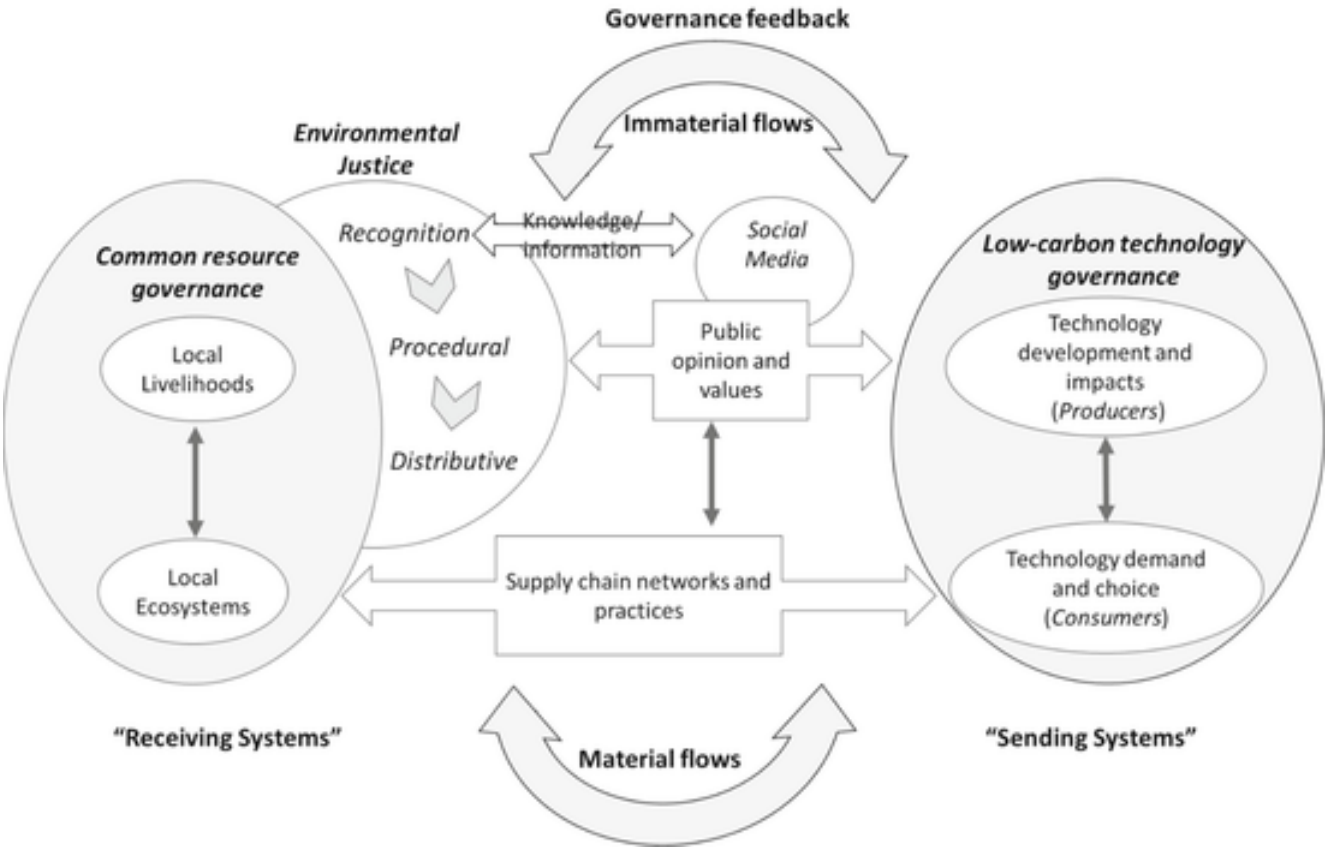


Fig. 1. Environmental justice and telecoupling framework that connects the "Receiving" and "Sending" Systems through the material and immaterial flows and governance feedback.

example [23–25]. Under specific social, political, economic, and environmental circumstances in producing and consuming nations, information regarding distal impacts can potentially produce change in consumer behavior and supply chain governance [26].

Telecoupling dynamics have inherent justice implications (Fig. 1). Sending and receiving goods across distance implies a redistribution of the environmental costs of their production; environmental inequality and distributive justice – the allocation of benefits and burdens – is thus prominent in telecoupled systems [27]. Furthermore, research that focuses on a product's end-use tends to lead to geographically bounded studies that ignore the transcontinental connections and other "sustainability telecouplings," such as environmental and social justice [6,28,29]. The neglect of these connections translates into *misrecognition*: a failure to acknowledge and legitimize specific social-environmental relations that are harmed, resulting in a blatant disregard, dismissal or inadequate acknowledgement of human and non-human claims against imposed burdens [16,27,30]. Examples of misrecognition include cultural and economic domination, processes that render people and places invisible, and discourse and practices that stereotype and denigrate individuals and social groups [30], all of which undergird the inequitable and unjust burdens of supply chain externalities. In the presence of misrecognition, affected populations have little opportunity for exercising *procedural* justice, or the right to participate in decision processes [25]. Recognition justice is thus often thought of as fundamental to achieving distributive and procedural justice, and misrecognition helps explain the persistence of distributive injustices [16,30]. For this reason, scholars have called for more research assessing, for example, transcontinental coal, oil, or biofuel supply systems involved in the mutual shaping of (un)sustainability dynamics at diverse localities across the North-South divide [6,31]. For example, extractions of lithium driven by increasing demand for electric vehicles (EVs), create environmental justice issues related to impacts to indigenous communities, fair wages, child labor, and other justice concerns in places far away from where EVs will be actually used [18].

Scholars increasingly acknowledge the social and environmental implications of critical mineral extraction [1,18,32], yet how such impacts should be governed remains unclear [33]. While much attention is cast towards the promise of corporate social responsibility in mineral governance, the mechanisms through which distal social and environmental injustices are communicated back to corporate actors is often ignored [33]. Given the prominence of critical minerals in supporting the global low-carbon transition, it is important to understand and manage the wider environmental and social implications of these impacts in the mineral-extracted places to enable a just transition that respects the rights of host communities and their living environment [20].

Our premise is that addressing injustices in telecoupled critical mineral supply chains requires explicit attention to how environmental and social harms are made visible to those actors with influence over supply chain practices, policies and institutions [8]. In essence, the channels through which impacts are recognized locally and then communicated to consumers, constitute a "return flow" from receiving systems back to sending systems in a telecoupled framework. This flow of information may be instrumental in enabling recognition justice, by rendering visible the social-ecological relationships of harm that would otherwise be disregarded or dismissed by supply chain actors that may be unwilling to assume responsibility for such harms. In turn, social media flows can bring attention to the distributive justice implications of mining, as well as the need for procedural justice to enable affected communities to participate in supply chain governance [27]. Once recognition justice is achieved, distributive and procedural justice can be more effectively realized because all populations – including socio-economically disadvantaged communities in telecoupled settings – are deemed legitimate [16].

Recognition of inequitable burdens implies that essential information concerning supply chain harms is available and communicated to supply chain actors. Recognition also implies that the social actors experiencing harm and injustice are able to exert their claims through communication and institutional channels available to them [27]. As Boillat et al. (2020) [27] argue, information flows in telecoupled systems are political and imbued with power and agency; flows that most authentically capture the claims of actors who might otherwise be *misrepresented* are thus of critical interest.

Social media is a form of communication that is potentially more directly accessible to individuals and thus, in theory, may be more democratic than other modes of communication [34]. As such, it offers promise for enabling recognition justice, with the potential to directly link affected actors to the representation and interpretation of their claims.[1] Additionally, independent of connections to justice concerns, researchers note that social media data are one way to assess immaterial flows in telecoupled systems [11]. While recent developments underscore how information platforms are often tied to the politics of platform ownership and government censorship, many of the more popular platforms such as Twitter, Tumblr, and Facebook have allowed motivated individuals and groups to participate relatively freely in communication and information transmission [34]. Loosely regulated participation has allowed such groups to express grievances or raise concerns about corporate activities independent of the control of the corporate entity or other organizations they are critiquing [35]. While this participation does not involve standards of evidence associated with news media, social media has enabled more community participation than would occur otherwise [34].

Related to supply chains, although social media assessment is a promising means of gaining insight into firms' management of and responses to supply chain events and stakeholder interests, its application is relatively nascent [36]. Social media entails relatively low cost to users and does not require a substantive time investment. These factors help facilitate the agency of populations and individuals affected by supply chain impacts to vocalize their concerns. Amplification of those concerns through the social networks represented in social media may thus constitute an important feedback – although potentially indirect – between the recipient and sending components of a telecoupled system. Nevertheless, it is also possible that the very attributes of populations and places that make them specifically vulnerable to *misrecognition* and associated injustices may also impede their access to social media to express their grievances [37]. Because concerns expressed in social media about environmental and social impacts do not adhere to standards of evidence, potential for misinformation is real [38].

Social media is often analyzed through the use of text analysis, such as sentiment analysis [39]. Topical trends in other digital media (digital news outlets, magazines) are being analyzed using platforms such as Media Cloud (e.g., [40]), NodeXL (e.g., [41]), and Google Trends (e.g., [42]). Despite a proliferation of such methods, there have been few applications on mining impacts.

In our analysis below, we use social media data (Twitter) to explore the propagation of information on the social and environmental externalities of lithium extractions in Chile. Our purpose is to assess what, if any, information signals can be attributed to Twitter data. We do not assess the empirical validity or credibility of any information transmitted, only the normative sentiment associated with such information. Ultimately, in understanding telecoupling dynamics, both misinformation and credible knowledge flows can be instrumental as system feedback and can potentially influence behavior of sending systems, albeit with distinct normative implications for sustainability. Whether or not social media is serving as a source of such feedback is an important first empirical step.

[1] It is worth noting that social media flows are also subject to power dynamics and can exacerbate misinformation considering the influence of specific actors in shaping discourse and narrative, owner or government controls over content in specific information platforms and politics of misinformation [37].

3. Research methods

3.1. Case study

The Salar de Atacama has been a source of lithium mining since the late 1990s. Before lithium mining began, the region was mostly uninhabited and used for agricultural purposes by indigenous communities. The vast salt flats were also a source of sodium and potassium for local mining operations. Water resources in the Salar de Atacama, Chile can be considered non-renewable because of the limited precipitation that falls directly on the salt flat (approximately 10 mm/yr) and the rapid rate of evaporation (approximately 0.1–1.1 mm/day) due to high elevation. Competition for scarce water resources and its impacts on local livelihoods and the environment have raised concerns about the sustainability of lithium production [19]. Furthermore, the operation of mining activity in Salar de Atacama is adjacent to protected wetlands that support diverse flora and fauna species and are one of the most important breeding habitats for endangered flamingo birds.

Water rights are particularly contentious in the region. Since the promotion of the Mining Code of 1983 under the Water Act of 1981, mining companies have been granted rights to the water found through exploration [43–45]. Many indigenous communities lost control of their water resources under the Water Act, prompting the introduction of the Indigenous Law of 1993. Indigenous Development Areas, overseen by the National Indigenous Development Corporation, were created in 1997; however, social mobilization around water issues has continued to rise [46]. Social justice concerns have coincided with growing concerns over environmental impacts, provoking an amendment to the Water Act to more strictly regulate the expansion of groundwater use in mining and to ensure ecological assets are better protected [47]. In November 2019, socio-political riots occurred in the nation's capital, leading to a referendum to reform the Chilean Constitution, related to, among other things, water private rights and the nationalization of the lithium mining industry.

3.2. Social media data collection and analysis

Our social media data were collected from Twitter for the period of 2015–2020. As one of the most popular social media platforms globally, Twitter provides a platform for individuals, groups, corporate entities or private companies and government agencies to post announcements, concerns, opinions or other information. According to recent market research [48], 82 % of Chile's population has consistent Internet access, and 92.8 % are social media users. OECD data indicate a 12.5 % difference in Chilean broadband access between urban (averaging 89 %) and rural (77 %) Internet users [49]. While we cannot assume easy access to Twitter as a social media platform, the penetration of social media and digital communication in Chile is advanced, and thus social media analysis has been used in recent research to assess diverse phenomena (e.g., [50,51]).

We acknowledge the presence of ethical issues regarding how Twitter data were collected and managed. Following Bruns et al. (2012) [52], we hold a view that Twitter data available through Twitter APIs and related tools were public information, and thus its collection and use did not require ethical review or special consideration. In our study, we were using the Twitter academic API through a python package "TWINT", treating Twitter data as a secondary data source as the data is gathered not from the participants but from an aggregating intermediary (Twitter). We have taken a precaution to deidentify public user data by removing names in the presentation of our findings, as suggested by Takats et al. (2022) [53] and Hunger et al. (2018) [54].

We used *TWINT* (https://github.com/twintproject/twint)), an efficient advanced Twitter scraping tool written in Python that allows for scraping tweets from Twitter profiles using Twitter's API to collect tweets. Our Twitter search focused on tweets that mentioned issues of environmental and social concern, and/or mining generally, *and* the Atacama region. We eliminated search terms associated explicitly with specific corporate actors and included terms to capture a broad range of environmental or social concerns that could emerge in conjunction with mining or independently of mining activities. We used *"((Atacama OR Atacameños OR Antofagasta) AND (protest* OR manifest* OR demonstr* OR bloque* OR environment OR ecosystem OR ambiente OR ecosistema OR Indigen* OR indigenous OR Right OR derech* OR agua OR water OR flamingo OR biodiversidad OR Mining OR Mineria OR Mina OR Mine OR turismo OR tourism))"* as the search query.[2] In order to collect as many relevant tweets as possible, we used both English and Spanish for each token in our search query, given that most tweets related to local issues were written in Spanish.

As the data show that there was limited local participation in online social platforms such as Twitter before 2015, we constrained our search to the date range from 2015/01/01 to 2020/07/31. We conducted our search on both local tweets (georeferenced in 600 km around Atacama) as well as global tweets (not georeferenced). We collected 1722 local tweets and 71,521 global tweets. The global dataset also contains the local tweets. Each tweet was analyzed according to various elements including tweet ID, Created time, Timezone, User ID, User name, Nickname, Geo Location, tweet Mentions, Urls, Photos, Replies count, Retweet count, Likes count, Retweet (True or False), Hashtags, Link, Video, Reply to and Language. We then applied natural language processing techniques and statistical analysis to our datasets to further analyze the data to detect the issues that were being raised and communicated, the primary actors (based on user's online activities, e.g., the number of related tweets) involved in communicating issues, and the flow of the information.

We first preprocessed the data using *NLTK* [55], a leading platform for building Python programs to work with human language data, to remove noisy information such as links and special characters. This step contains four steps namely: punctuation removing, tokenization, stopwords filtering, and stemming (details of the steps are provided in the Supplementary Information).

We then employed a large language model (LLM) to perform sentiment analysis. An LLM is essentially an advanced AI model that has been initially trained on a vast amount of text data from the internet and later fine-tuned on a specific task – in this case, sentiment analysis. Sentiment analysis is the process of determining the attitude or the emotion of the writer [56]. Each tweet was classified as positive, negative, or neutral. Since our collected tweets were written in English and Spanish, we applied multilingual XLM-roBERTa-base model *(https://huggingface.co/cardiffnlp/twitter-xlm-roberta-base-sentiment)*, which is a state-of-art large language model (LLM) trained on ~198 M tweets and fine-tuned for sentiment analysis across 8 languages [53,57]. We employed a sequential validation and verification procedure for the sentiment analysis as described in Mozetič et al. (2018) [58].

Second, we applied N-grams analysis to our dataset. An N-gram is one of the essential concepts in text analysis. An N-gram is a set of co-occurring or continuous sequences of n items from a sequence of large text or sentence. For example, 1-g (unigram) represents unique words in the sentence while 2-g (bigram) represents the combination of two consecutive words and their frequency of occurrence. In our work, we used NLTK to perform unigram, bigram and trigram in preprocessed tweets. We then sorted the results to capture the top 30 N-grams to pro-

[2] The term "flamingo" translates similarly in both English and Spanish. However, "biodiversidad" does not, and so we may have inadvertently missed some English references to "biodiversity" by inadvertently excluding it as a search term. Because of changes in Twitter's policy of data acquisition, we were unable to repeat our search string post-hoc with the addition of the term "biodiversity." This may have reduced the number of Tweets we selected in our search. However, we expect that the impact of this omission is small given the wide array of other relevant terms that our search query.

vide insights into the topics and issues that were of greatest concern to the Twitter users.

Third, we applied several statistical tasks to analyze our data: 1) Top 30 mentioned users: Twitter users can use the "@" symbol with a username to signal to other Twitter users to look at a specific post. We sorted the top mentioned users in our dataset. 2) Top 30 hashtags: Twitter users can add hashtags ("#" symbol) in front of a key phrase or term in their post to signal the topic or theme of a specific post. 3) Top 30 senders: The users were sorted based on the number of tweets they sent in our dataset.

3.3. Network analysis of tweets

We use the calculated centrality measures of the resulting network to understand and analyze various aspects of the network's structure and dynamics [59]. The particular measures considered include *average degree* (a measure of network connectivity), *average path length* (a measure of ease of communication within the network), *graph density* (a measure of network density), *degree distribution* (a measure of connection frequency), *degree centrality* (a measure of direct connections a user has in the network), *betweenness centrality* (an indicator of intermediary role in the network), and *eigenvector centrality* (a measure of the number and quality of connections a user has). A more detailed description of centrality measures can be found in Supplementary Information, SI-Table 1.

Finally, we conducted a network analysis on the Twitter data for the period 2015–2020 using the Gephi software (Gephi.org). The software is an open-source tool designed for visualizing and analyzing networks, which has been used in various fields, including social network analysis, biological networks, and transportation networks [60].

4. Analysis and results

4.1. Timeline of Twitter chatter

We pursued two strategies with the same search string: a focus on local tweets and the global Twitter feed over the same time period. We see two contrasting temporal dynamics. Georeferenced tweets ("Local") were much less abundant than non-georeferenced ("Global") tweets and generally increased towards 2019–2020. This period coincides with significant political activism in critique of public policy in Chile, in which environmental concerns were also featured. In the "Global" Twitter feed, we found constant chatter on Twitter, dropping in 2016–2018 before rising (Fig. 2).

4.2. Key issues of tweets based on the complete dataset

We first determined the key issues of the complete dataset ("Local" and "Global" tweets) using bigram and trigram analysis. Isolating our analysis to local tweets may appear to be overly constraining in that we created a smaller pool of active Twitter users where mining is occurring, thus leading to and a greater likelihood that the sample consists of tweets that are dominated by one or two users who were particularly prolific but not necessarily salient. However, after we removed these non-salient users from the dataset.

The analysis indicated controversy over water impacts of mining as represented by the keywords: "without, water", "water, cut", and "mining, companies" (Bigrams; Fig. 3a) and "water, cut, affect" and "without, drinking, water" (Trigrams; Fig. 3b). The tweets also covered some other major topics including ways to increase water supply through fog collection techniques (e.g., "fog, catchers") and an indication of negative effects on the tourism sector (i.e., "tourism, starting, bleed"). Moreover, some of the top keywords simply highlighted the geographical context of the mining activities as one of the driest places on Earth (e.g. "salar, Atacama" and "driest, places, world".

4.3. Sentiment analysis of tweets

We then assessed the sentiment of the "Local" and the "Global" tweets. Fig. 4 shows the proportion of tweets with negative, neutral and positive sentiment over the study period. In both datasets, tweets with neutral sentiments dominated, which suggests that most tweets contained information, facts, or observations about the issue of mining impacts without any personal bias or subjective judgment. Of particular interest are the negative-sentiment tweets that indicate a feeling of dissatisfaction, unhappiness, anger, disappointment or frustration) towards the concerns about the environmental and social impacts of lithium mining in Salar de Atacama.

For the local tweets (Fig. 4a), the negative and positive sentiments closely followed each other's count and pattern. Starting late 2019, however, local tweets with negative sentiments were slightly higher than positive ones. In contrast, for the global tweets (Fig. 4b), negative

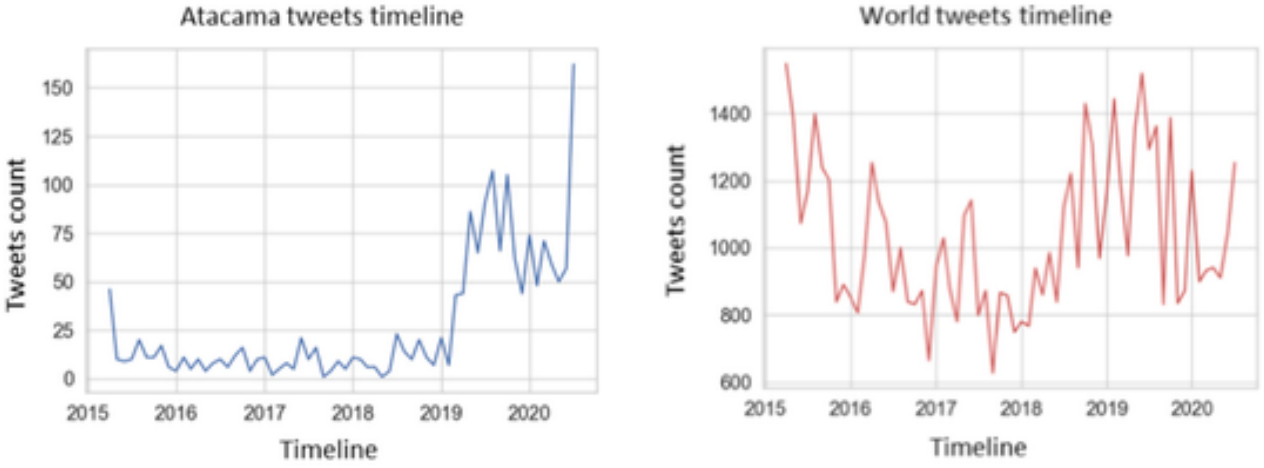
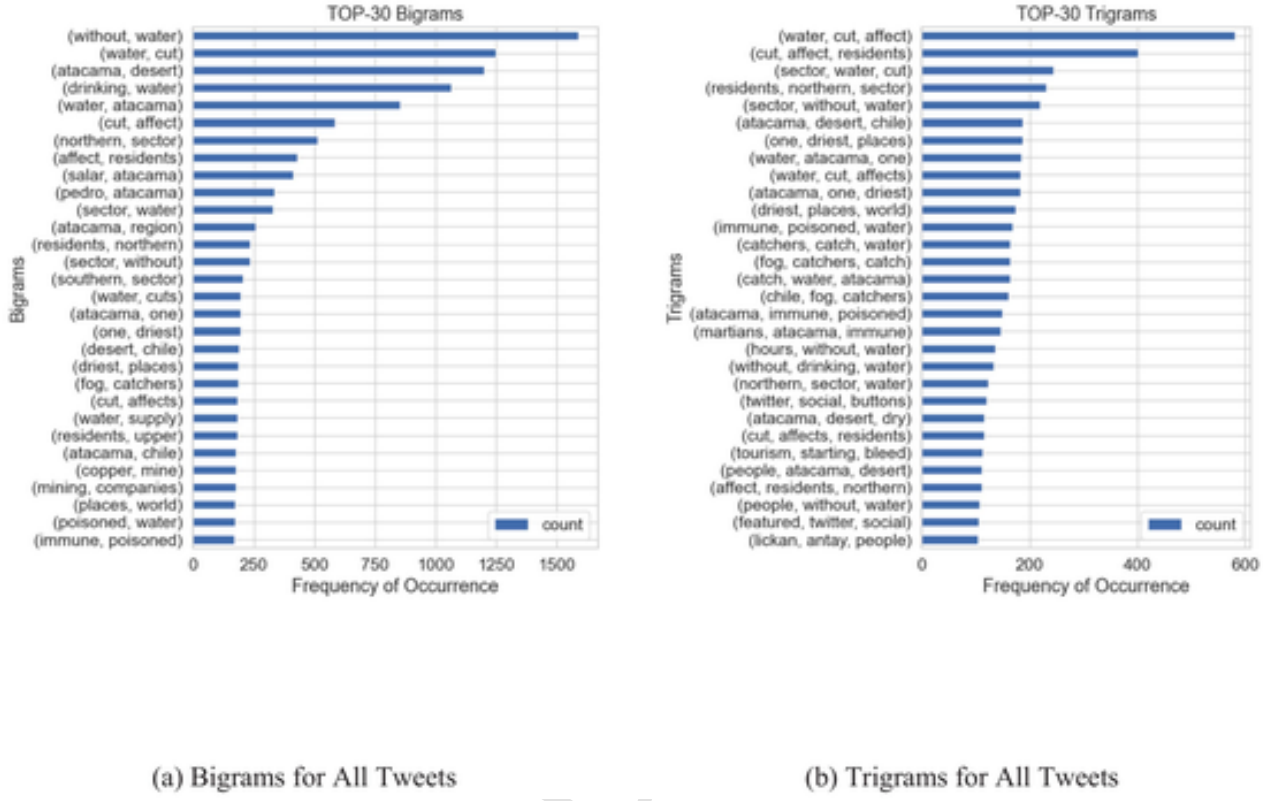


Fig. 2. Timeline of Twitter chatter at (a) "Local" and (b) "Global" tweet datasets.



(a) Bigrams for All Tweets (b) Trigrams for All Tweets

Fig. 3. The bigram and trigram of all tweets ("Local" and "Global"). The vertical axis shows the combination of words in tweets and the horizontal axis shows the frequency of occurrence of those words.

sentiments were slightly higher throughout most of the study period. The spike of negative sentiment in early 2015 for the global tweets can be attributed to the start of protests against mining impacts in the Atacama region [20]. Overall, our analysis of data subsets reveals that the "Local" and "Global" tweet datasets have 24.5 % (422) and 28.6 % (20,455) of negative-sentiment tweets respectively.

Next, for the "Global (mining AND water)" subset, a different pattern emerges (Fig. 5). Focusing on the specific terms of "water" and "mining" increases the proportion of negative tweets (Fig. 5a). As expected, in contrast to the "Local" and "Global" tweets (Fig. 4), the negative-sentiment tweets exceeded the neutral ones in several instances, especially after 2019. A slightly different pattern occurs for the "Global (mining AND water) (top users)" subset (Fig. 5b). The number of negative-sentiment tweets was smaller than the neutral ones in most instances. Overall, a sentiment analysis of the "Global (mining AND water)" and "Global (mining AND water) (top users)" subsets identified 44.1 % and 29.6 % of tweets as having a negative sentiment.

4.4. Key issues of tweets based on a dataset of interest

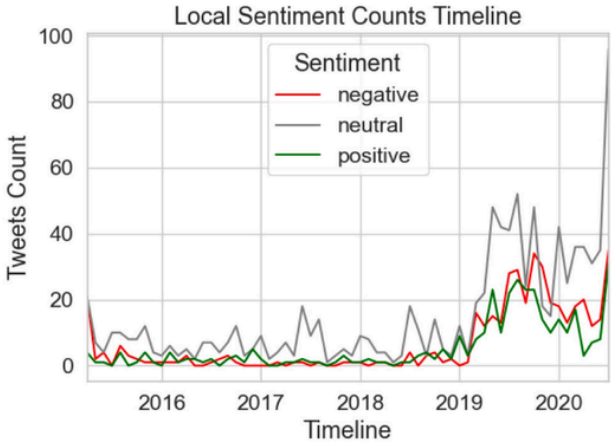
Given that water and mining were clearly the thematic focus of the tweets we had captured, we conducted further analysis of those tweets that specifically mentioned these two terms together: "mining AND water". The resulting sample was very small for the "Local" tweets ($n = 5$) because only about 1 % of the tweets on Twitter are place-tagged or coordinates-tagged [61] and hence the data were insufficient to evaluate in any depth. For the "Global" subset, the result consisted of 1235 tweets, which we refer to as "Global (mining AND water)" data subset. We then selected the top 30 most prolific Twitter users to further evaluate what these prolific Twitter users were communicating and to whom. This data subset is referred to as "Global (mining AND water) (top users)".

In particular, the negative sentiment tweets (see Section 4.3 above) within the "Global (mining AND water) (top users)" data subsets illustrated concerns about water scarcity. These concerns are represented by keywords such as "almost, dry", "dry, extraction" (Bigrams; Fig. 6a) and "salar, almost, dry" (Trigrams; Fig. 6b). They also suggest themes of contamination and waste with water and mining in the region through keywords such as "contamination, mining", "water, contamination, mining". They also indicated opposition to mining due to its water impacts through keywords such as "doubts, persist", "water, rights", and "doubts, persist, water".

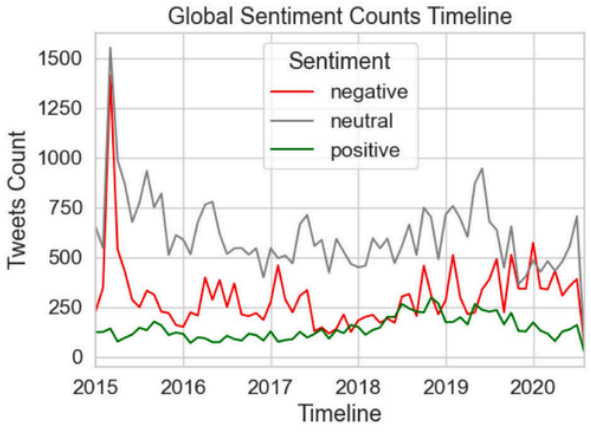
4.5. Network analysis of tweets

The network analysis on the "Global (mining AND water)" data subset reveals that the initial Twitter network contains 570 users and 470 connections (Fig. 7a). The majority of Twitter users (close to 70 %) and their connections are isolated. The network statistics, including the degree distribution, indicate that the tweet network is sparse (average connection per user of 0.825) and resembles a scale-free network with many users with few connections and a few users with many connections [62]. The majority of the connections are made up of small clusters of tweets that are disconnected from each other.

To obtain more meaningful patterns on the network, we focused on a set of interconnected elements, excluding small detached groups of users (Fig. 7b). Compared to the initial tweet network, the screened structure is smaller in terms of number of users and connections (30.9 % of all users and 37.9 % of all connections). The network connectivity, however, increases in *average degree* (i.e., the average number of connections a user has to other users), *average path length* (i.e., an indicator of ease of connection), and *density* (i.e., the portion of the potential connections that are actual connections) by 1.2, 1.05, and 12 times, respectively (see Supplementary Information, SI-Table 2 for the degree measures in more detail). Increased values of the degree measures

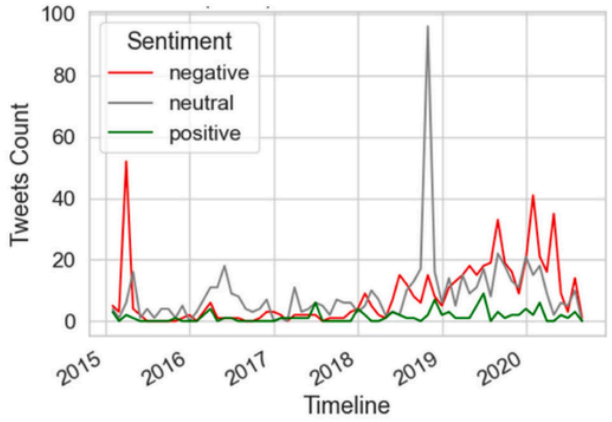


(a) Local tweets (All)

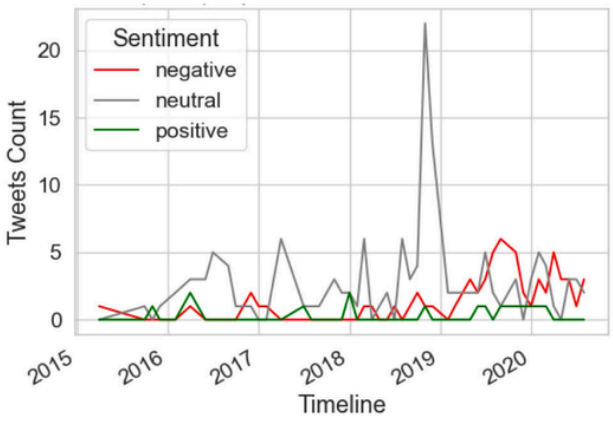


(b) Global tweets (all)

Fig. 4. Sentiment analysis of "Local" and "Global" tweets over the 2015–2021 period.



(a) Global (mining AND water) tweets



(b) "Global (mining AND water) (top users)" tweets

Fig. 5. Sentiment analysis of tweets that specifically mentioned the terms "mining AND water" together.

mean that the network is more dense with a shorter path of connection among users.

Furthermore, to better understand how Twitter users were interconnected and influential we partitioned the network based on modularity, which resulted in five distinct "communities" (Fig. 8). We analyzed three centrality characteristics of the network. First, based on in-degree centrality, we can rank the Twitter users based on the number tweets they received (Fig. 8a). One example of influential users is [User#1], a news media outlet in Chile. Its coverage on the issue includes articles such as (in Spanish) "Atacama: lithium exploitation leaves indigenous communities and residents without water" [63].

Second, based on out-degree centrality, we can rank the Twitter users on the tweets they sent out (Fig. 8b). One such influential user is [User#2] (with 932 Following, 493 Followers as of November 2020), who is an individual user expressing his/her concerns with tweet messages such as "Lithium extractivism threatens life and water in San Pedro de Atacama - Ecosystems" and "Because the life of the Salar de Atacama is worth more than its lithium, I APPROVE." This "I approve" message, in particular, was part of the campaign for a referendum for constitutional reform in Chile, which could affect mining companies' rights to use water for mining activities.

Third, based on eigenvector centrality, we can rank the Twitter users in terms of how influential their position is in the network (Fig. 8c). A user with such a prominent role is [User#6], which is an organization representing local Atacamenos people with 1124 Following and 1464 Followers (as of November 2020). This is an example of a role filled in by an NGO to channel and amplify socio-environmental concerns.

4.6. Analysis of actor types and their connections

We categorized Twitter users into seven categories: individual (IND), news media organization (NM), governmental units (GOV), private sector (COM), international governmental organization (IGO), non-governmental organization (NGO), and suspended users (DNE). Using four centrality measures, we analyze the characteristics of interactions among different actors (Fig. 9). The size of the bubbles indicates the magnitude of the respective centrality measure. The "half-moon"-shapes represent the tweets that were exchanged among the same type of actors. The width of the arrow is proportional to the number of exchanged tweets.

Based on the out-degree measure, individuals sent the most tweets followed by NGOs and the news media (Fig. 9a). On the receiving end, the news media were the target followed by the government units and NGOs, with the private sector coming fourth (Fig. 9b). These results imply a concentration of concern lies in individuals. A dominant strategy for voicing such concerns is not through going directly to mining companies (e.g., to change their practices) but indirectly through news me-

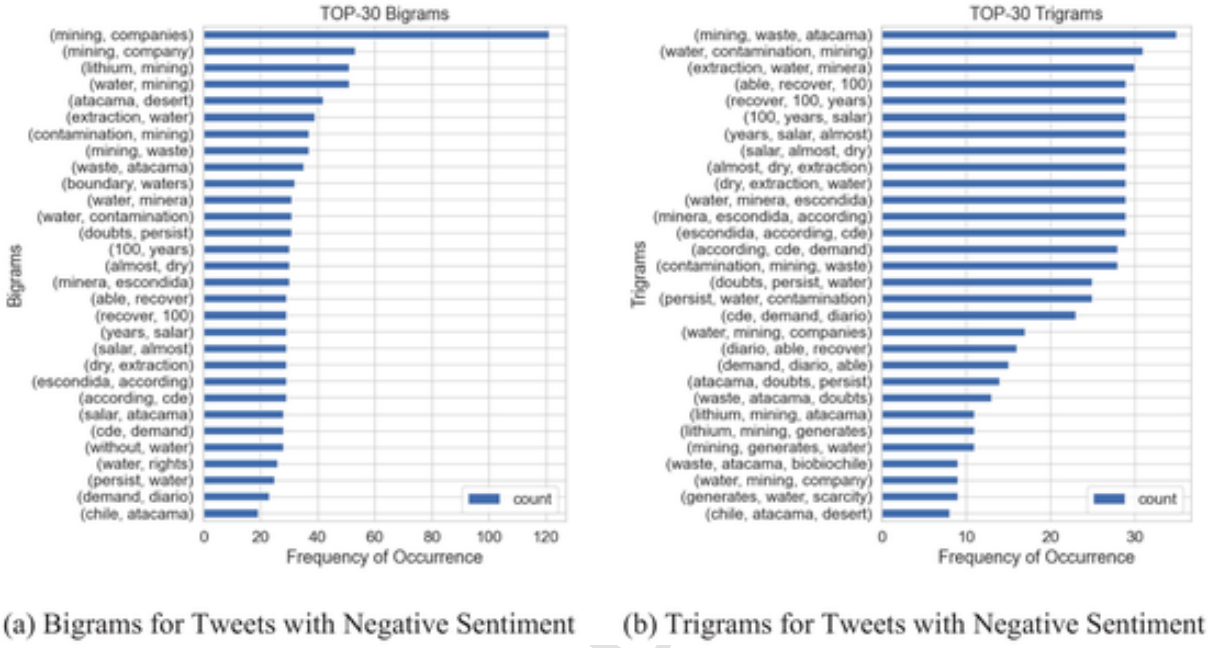


Fig. 6. The bigram and trigram of "Global (mining AND water) (top users)" tweets with negative sentiment only.

dia and NGO (e.g., to raise and amplify awareness about the issue) and government (e.g., to affect changes through regulatory measures).

The analysis also reveals influential actors in the network based on the betweenness centrality measure, NGOs and news media, as expected, play an important role in facilitating information flows across different types of actors (Fig. 9c). In contrast, based on eigenvector centrality, an actor's influence is determined based on the number of connections it has to other actors in the network and how important those actors are (Fig. 9d), thus serving as important information amplifiers. In this case, government actors and news media are highly influential; in comparison, the influence of NGOs and individuals is less. These results may imply that Twitter users assume these two actors - government and news media - to be influential in voicing or amplifying their concerns.

4.7. Geographical distribution of tweets network

To get a sense of the spread between local and global Twitter activities, we filtered tweets that contain geolocation information (i.e., latitude and longitude). Of the 0.15 % (141 out of 71,512 connections) of the total tweets that have such information, their location distribution and in-and-out degree characteristic is shown in Fig. 10.

The geographical distribution indicates that most conversations surrounding lithium mining and water issues took place domestically in Chile (Fig. 10a). They are distributed across the country. Most tweets took place in places that are closely associated with lithium mining including San Pedro de Atacama (main settlement nearby the lithium mining sites), Antofagasta (the provincial capital where the mining activities take place), and Santiago (the administrative capital of Chile). Few users outside the country were involved in those connections (Fig. 10b). Those that were involved represent a diversity of actors, including from the private sector, individuals, international and non-governmental organizations.

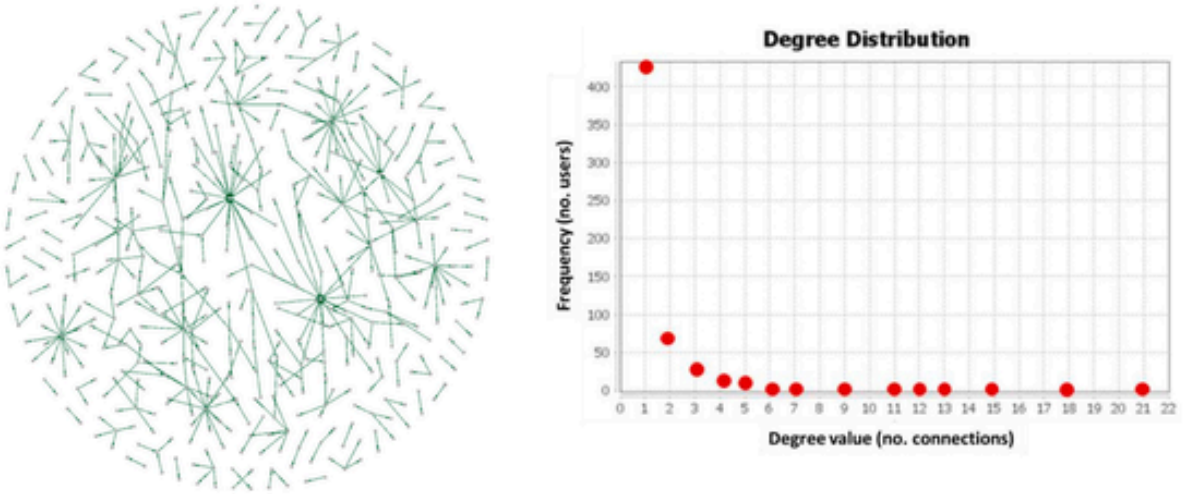
5. Discussion

This research assesses the promise of social media as a means to telecouple distal local communities and deliver information about environmental and social harms, thus acting as a tool to advance recognition justice. Drawing on a case study of lithium extractions in Chile, we assess how social media (Twitter) discusses the impacts of mining activities, which actors are involved in this social media communication about mining impacts, and how these actors are interconnected geographically.

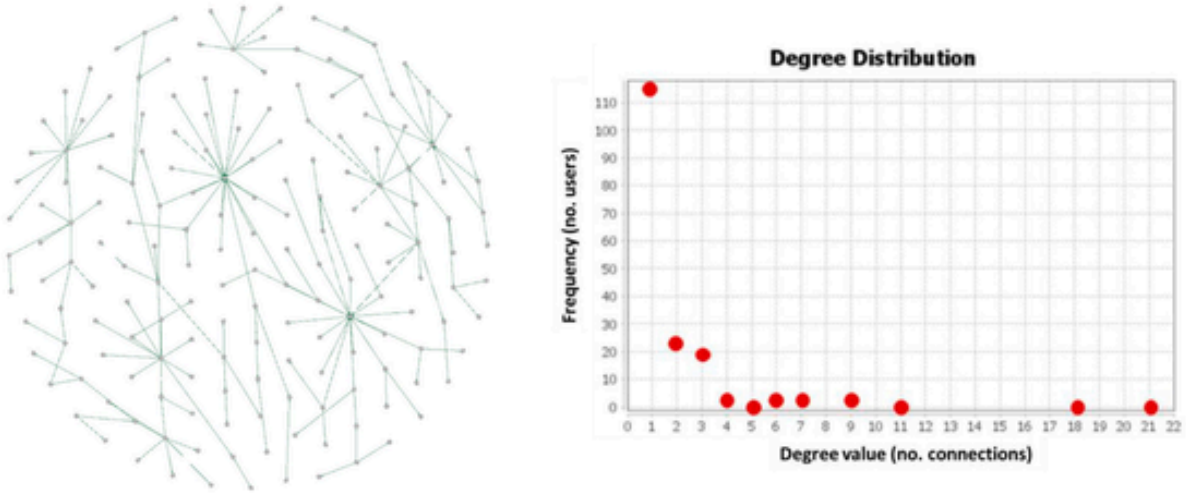
5.1. Lessons learned

While there is growing concern about the sustainability implications of the surge in EV adoption [18,64], information about such impacts is not always available. Complicating matters is that corporate reporting can be incomplete and fragmented across complex networked supply chains, creating significant information asymmetries between local communities affected by mining, companies that source materials from these mines, and consumers [65]. Our analysis illustrates that social media are a vehicle to enhance information flows on the distal direct and indirect impacts of mining of lithium for EV batteries and provide insights into what issues are being raised, by whom, and how these concerns are communicated, and to whom. Social media users who are critical of mining activities are using Twitter to voice their concerns in regions of mining activity, thus creating *opportunities* to reduce misrecognition. Our approach identifies which types of actors are discussing their concerns about the sustainability impacts associated with critical mineral mining, in addition to which organizations are taking on prominent roles as information connectors and amplifiers. Our findings illustrate the channels through which impacts are recognized locally and then communicated to EV users, constituting a "return flow" from receiving systems back to sending systems in a telecoupled framework, thus creating important visibility for the social-ecological relationships of harm that could otherwise be disregarded or dismissed by supply chain actors that may be unwilling to assume responsibility for such harms.

While the georeferenced Tweets were only a small percentage of the total analyzed, our exploration of those Tweets also illustrate how messages are communicated across geographies. We can assume that many non-georeferenced Tweets also originate in Chile and are being picked up by Twitter users in distal geographies. Although extrapolating communication patterns observed in georeferenced Tweets to the broader Twitter information flow is not possible [66], even if the georeferenced Tweets are not representative of the patterns of information flows in the



(a) Initial network of all tweet users and its degree distribution



(b) Tweet network with only interconnected users and its degree distribution

Fig. 7. Characteristics of the tweets network in terms of its degree distribution (i.e., the frequency with which users in a network are connected to other users).

global sample, these flows illustrate how Twitter messaging can span geographies. Shifts in awareness about social-environmental impacts are potentially as much about the volume of information flow as they are about the power and message amplifying capacities of the specific Twitter users who are in communication.

Related to the specific sustainability topics being communicated, our analysis of the Twitter feed identified that water and mining were the most frequent topics. Additionally, our sentiment analysis of those tweets indicated concerns over uncertainty as mining activities unfolded. The temporal dynamics and thematic foci of tweets we captured could potentially serve as early warnings to supply chain actors that thresholds of local attention and social concern are being approached and supply chain action is needed to manage increasing risk.[1 and 2]

The extent to which Twitter is actually serving to address *misrecognition* in the mining of critical minerals is still unclear. On the one hand, our analysis reveals local concerns over water in relation to mining, which are issues that are likely poorly understood by many consumers of EVs [26]. Lithium is particularly water intensive and the co-occurrence of lithium deposits in salt flats, with specific ecological attributes, distinguishes such mining activities from other forms of mineral extraction. On the other hand, recognition of the environmental cost of lithium mining is not the same as recognition of the socio-cultural and economic values and livelihoods that are also affected by mining, beyond concerns over water access and quality.

Other academic analyses, for example, have identified other related harms to Indigenous culture and way of life [46,67]; these cultural di-

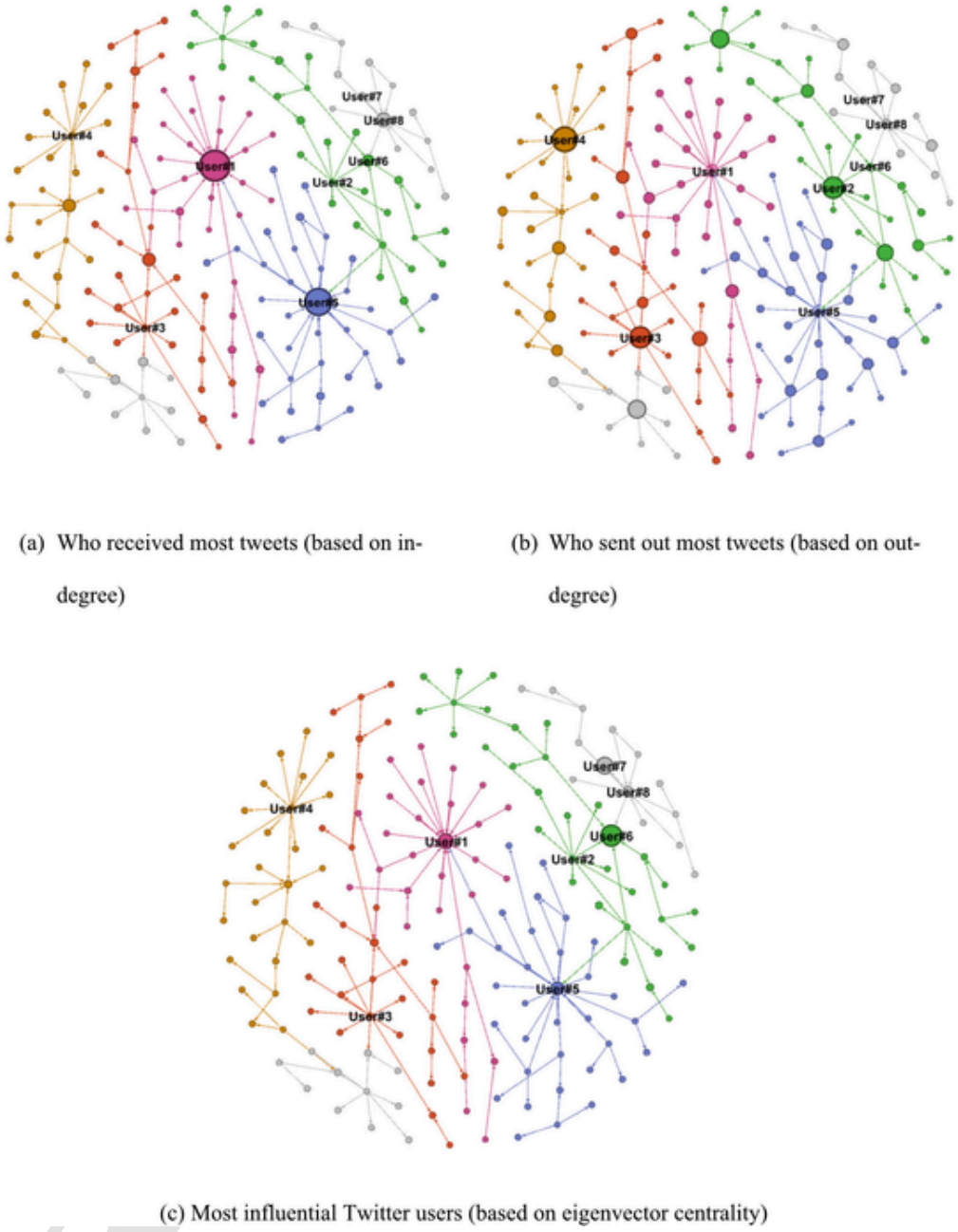


Fig. 8. Characterizations of Twitter network centrality based on five distinct "communities" (represented by five different color codes). The size of the nodes is proportional to the magnitude of the respective centrality measure.

mensions of harm were not obvious in the Twitter feed. Bolliat et al. (2020) [27] stress the need for researchers of telecoupling to go beyond the social outcomes associated with ecological change to consider direct social impacts embroiled in telecoupling dynamics. Nevertheless, the communication of such direct impacts from Twitter also requires that actors associated with such impacts are able and empowered to use the platform as a means of expressing their claims. Our dataset identified one Twitter user who appeared to represent Atacamenos people. These findings offer some support for the idea that the issues being discussed are in relation to the interest of local 'publics,' some of whom may represent Indigenous interests. Additionally, our analysis offers further evidence (e.g., [34]) that relatively few actors/users are responsible for a significant portion of Twitter volume. In the remote region where mining is occurring, access and use of smart phone technology is likely limited, despite the fact that over three-quarters of rural residents are reported to have broadband access, and cellphone use is widespread [48]. What issues are raised and why ultimately reflects the interests of those actors who have access to the communication technology. Additionally, the sentiment of Tweets regarding mining is subject to commercial propaganda from mining and EV enterprises just as it may be expressing interests of more populations affected by mining activities. How specific user interests serve to channel specific issues into national and international networks of attention can reflect *misrecognition* as much as *recognition*. Should concerns increase over mining impacts, for example, local actors with vested interest in mining – and potentially disproportionate capacities to access media platforms – may be mobilized to use social media to counter or discredit such claims. Very few organizations and groups will necessarily have the capacities, tools and connectivities available to them to raise their concerns to a global audience [68].

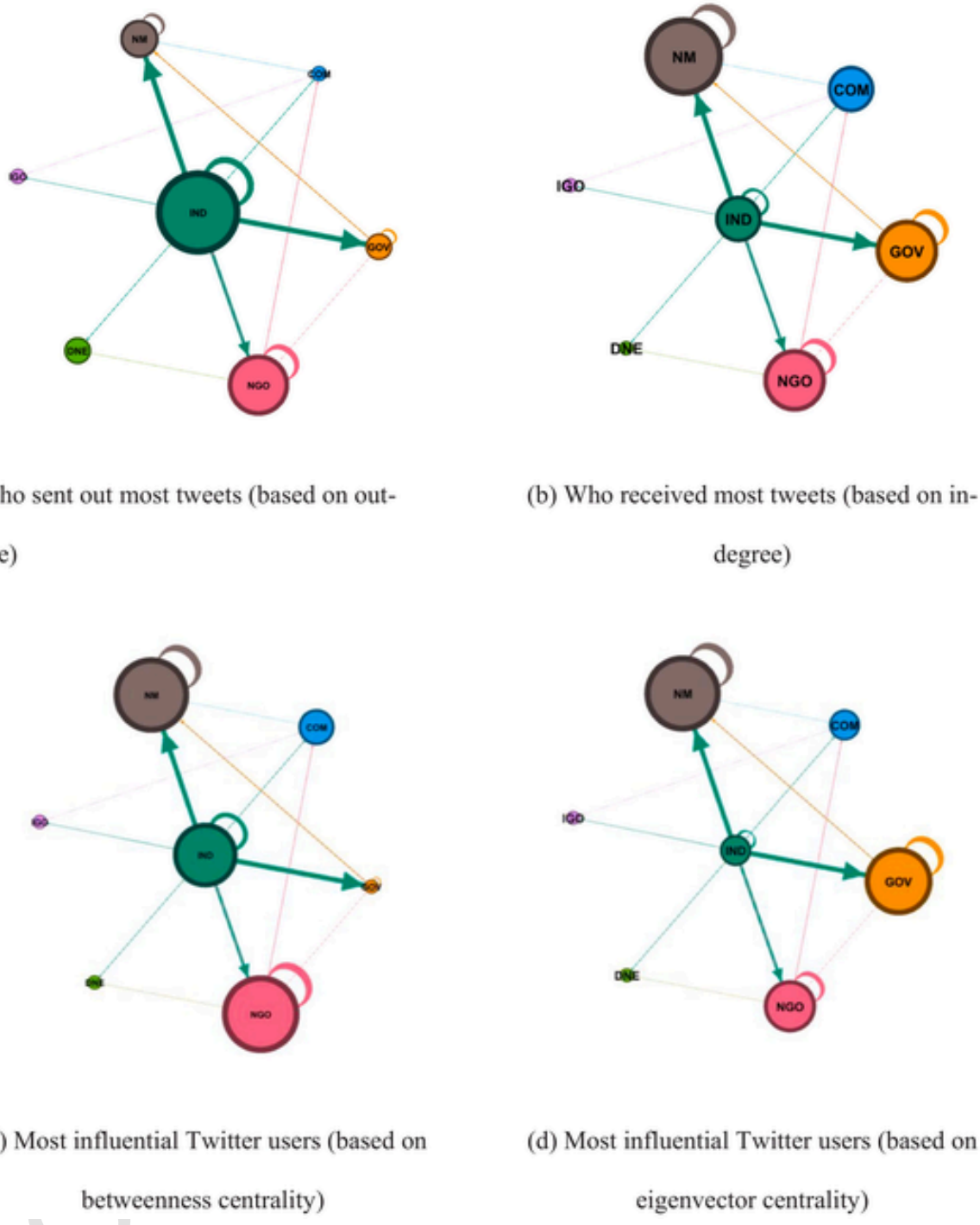
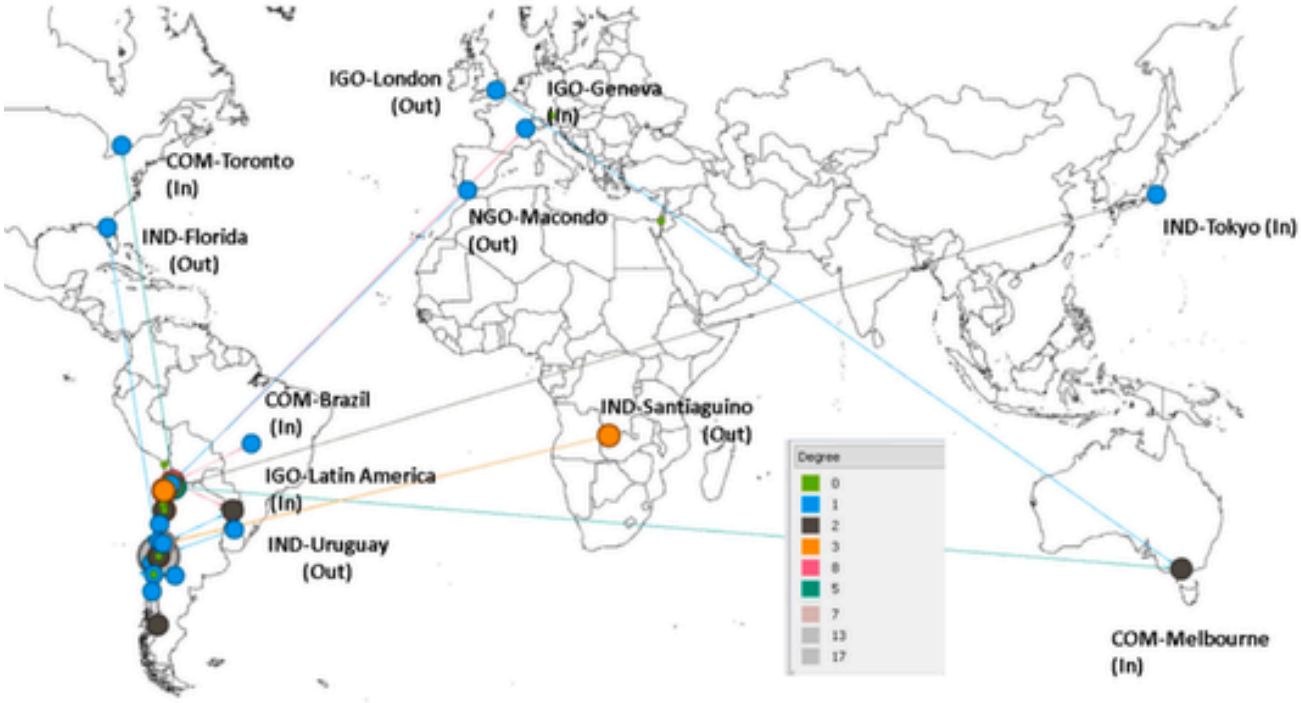


Fig. 9. Network analysis of actor types on the issue of mining and water impacts
Legend: individual (IND), news media organization (NM), governmental units (GOV), private sector (COM), international governmental organization (IGO), non-governmental organization (NGO), and suspended users (DNE).

Our analysis appears to capture communication patterns that reflect the strategies of social mobilization raised by Boillat et al. (2020) [27] – e.g., how actors may intentionally seek allies in their communication networks to amplify their concerns and address power asymmetries in voicing their claims ("boomerang effect"). For example, despite the prominence that "company" and "companies" play in the content of all and negative tweets (in the top ten words / bigrams / trigrams) it appears that the individuals who most frequently raised concerns over an outcome or occurrence related to water and mining tended to target other actors who could amplify their message (NGOs or news media) or to government actors, who perhaps are targeted because of their formal responsibilities for addressing concerns raised by citizens through regulation. Other analyses have found interactions among the news media and Twitter, documenting how both are generally reactive to events, and that the news media often serves to amplify issues that are already trending on Twitter [35].

Twitter data offers important promise in illuminating emerging sustainability issues associated with critical mineral mining. To analyze this data, we had to determine an appropriate search query that would allow us to explore any environmental and social implications that

(a) Chile domestic tweet network



(b) Global tweet network

Fig. 10. Geographical distribution of Twitter users both domestically and globally. The node color denotes the number of connections (degree) each Twitter user has.

might be associated with mining, without knowing, a priori, which such concerns might be. Our initial search query captured a significant amount of "chatter" related to general supply chain information and news, a large part of which consisted of industry propaganda and brand dissemination. This discovery suggests that social media is likely being used increasingly by firms to boost their legitimacy and brand awareness through messaging, and, indeed, Gómez-Carrasco (2020: 27) ([35] pg. 27) argues that "Twitter is used [by firm] as an instrument for legitimacy rather than to engage with stakeholders and assess their concerns." By eliminating corporate names from our query, and not forcing

a relation to mining in our Boolean construction (at least initially) we were able to evaluate what social and environmental issues were being raised in Twitter and the extent to which any issues were being associated with mining terms. As we homed in our analysis on "mining AND water" we were able to gain additional insights – namely that water concerns were emerging in relation to terms like "cut" "contamination" "doubt" and "uncertainty" suggesting local tensions in communication and the implications of mining for water resources. Such iterative query construction and learning is likely to be an important strategy in such exploratory research using "noisy" data such as Twitter. The network analysis illustrated how specific key actors have connectivity that can mobilize messages across geographies, potentially allowing for the "scaling out" of information flows that may prove instrumental in communicating sustainability concerns in mineral supply chains. The fact that our analysis identified at least one Twitter who appeared to be representing more collective interests of the Atacamenos peoples illustrates how even in remote contexts, Twitter may be an important tool for social mobilization and communication.

5.2. Future research

Our analysis presents several interesting and promising directions for further exploration. Prospective research would benefit from empirically assessing the relationship between the different types of justice – recognition, distributive, and procedural – in the dynamics of telecoupled flows, and, in particular, in relation to the type of flows associated with specific justice processes and outcomes. Prior research suggests that recognition justice is thus often thought of as fundamental to achieving distributive and procedural justice [16,27]. However, what remains unclear is the measurable improvements to distributive and procedural justice when recognition justice is in place. The results of our research focus specifically on *recognition* justice and the promise that social media offers in advancing this type of justice through information flowing from receiving systems back outwards towards sending systems. Future research should consider how other flows may also be prominent in distributive justice, e.g., flows of finance and earnings, material flows of water, minerals and goods, and of people. Procedural justice also will likely entail distinct actors and flows of knowledge, people and finance. Immaterial (values, rights, norms) and material flows (resources, people) associated with procedural justice may also involve distinct geographic and actor constellations, with both local-level action (e.g., local participation in national policy making) and distal action (local level representation in international or transnational governance processes) prominent. While recognition justice is fundamental, it may occur and evolve in tandem with action in distributive and procedural domains, raising important questions about the temporal dynamics of justice in a telecoupled system.

Additionally, social media information comes in various forms, such as text, images, and videos. An important extension to our research findings would be to expand the types of communication considered. The sort of media preferred users in "sending systems" may be, however, distinct from that most used in "receiving systems" – connections across media platforms (such as from Twitter to traditional news media and vice versa). For instance, producers who are targeted in social media tweets (through mentions or hashtags), particularly in relation to messages of negative sentiment, are not likely to use Twitter to directly respond [35], in part because organizations have a difficult time controlling these narratives. So while Twitter may be an important feedback mechanism conveying information on distal supply chain externalities and social-ecological implications of supply chain activities, it is difficult to demonstrate *how* such information is acknowledged and received by the producers whose headquarters are located in Chile and globally, or the EV battery consumers who are the originator of much of the growing mineral demand. Understanding these pathways are an important step towards further advancing recognition justice by acknowledging and legitimizing human and non-human claims against imposed burdens [16,27] and addressing the (un)sustainability dynamics at diverse localities across the North-South divide [6,31].

6. Concluding remarks

Decarbonizing energy and transportation systems requires low-carbon technologies such as electric vehicles and renewable energy. Such efforts have led to increased demand for critical minerals such as lithium and international mineral trades between the Global South (where most of minerals are extracted) and Global North (where most of the technology products are consumed). Within this context, there has been a growing acknowledgement that the local impacts of mineral extractions on the wellbeing of local communities (including indigenous people) and the health of local ecosystems cannot be ignored. These impacts are the source of significant inequalities exacerbated by the distal nature of the mineral supply chain [32,69]. Addressing such impacts will improve justice outcomes in society in the areas such as taxation, environmental impact assessments, waste management, social license to operate, and cross-border actions [32].

This research provides initial evidence of the potential role of social media as a mechanism to enhance information flows and knowledge from sites of mineral mining "outwards" into social networks that could serve as vehicles for informing mineral-consuming publics. Indeed, social media may be an important tool to telecouple local concerns across the critical mineral supply chain and give voice to local stakeholders who otherwise are not heard, thus enhancing recognition justice for these distal communities.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.erss.2023.103264.

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