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The Apaguen los Mecheros campaign: Supporting climate justice in the Amazonian cities of Ecuador by estimating the health risks of gas flaring

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HIGHLIGHTS

- 294 gas flaring sites in Ecuadorian Amazon impact populated centres.
- Gas flaring poses Moderate Risk on 99,918 people's health in Amazonian cities of Ecuador.
- Gas flaring poses Very High Risk on 12,718 people's health in Amazonian cities of Ecuador.
- 180 populated centres are in a 5 km radius from 6 to 18 gas flaring sites.
- Grassroots and indigenous movements can have an active role in shaping just futures enforcing Actions for Climate Empowerment.

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ABSTRACT

On 26 January 2021, the Court of Nueva Loja banned oil-related gas flaring (GF) activities in the Ecuadorian Amazon Region (EAR), establishing a term of 18 months for GF sites 'near populated centres' and until 2030 for those remaining. However, it is still unclear how the ruling will be applied.

The present study investigates the impact of GF sites on Amazonian settlements to support the application of the ban. This research is part of the Extreme Citizen Science process carried out by the Apaguen los Mecheros campaign—one of the main claimants in the trial.

To estimate the impacts on populated centres and four Amazonian cities, literature data on GF impacts were used to create three risk scenarios: very high-risk scenarios (VHR) within 0.65 km, high-risk scenarios (HR) within 2.25 km and moderate-risk scenarios (MR) within 5 km.

The results highlighted that 294 of 295 GF sites affect at least one populated centre in the MR and should thus be shut off. Additionally, 92 populated centres are affected in the VHR, 318 populated centres are affected in the HR and 711 populated centres are affected in the MR, while 180 populated centres are affected simultaneously by 6–18 GF sites in the MR. The results also show that 99,918 people in Amazonian cities may be currently affected by the MR, and more than 12,000 are affected in VHR areas.

By applying different metrics found in literature, the research provides the first assessment of the risk posed to the health of local communities for GF in the EAR. The results are being used from members of campaign in the trial, showing how participatory processes can support the grassroots and indigenous movements taking action to shape just futures.

1. Introduction

1.1. Climate justice: a transcalarity approach

Climate change caused by humans is an established fact, and the climate crisis is recognised as the most important and complex challenge facing humanity (Rogelj et al., 2018). The current goal of global climate governance is to limit the global average temperature increase to 1.5 °C, with a maximum of 2 °C, as stated in the Paris Agreement (Arnell et al., 2018). In this context, the concept of climate justice, which has gained increasing importance over the last 20 years, highlights the need for equity and social distribution when evaluating climate change and how

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we will address it (Robinson & Shine, 2018). Thus, the demand coming from the climate justice movement extends beyond ensuring the transition to a carbon–neutral and climate resilient economic system without compromising the safeguarding and protection of human rights and including all populations' rights to development. Substantial changes are needed in patriarchal and colonial capitalist systems at the core of climate change and climate injustice (Sultana, 2022a).

Industrialization, the primary driver of climate change, has benefited the Global North, while the cost in terms of climate impacts affects the entire global community. Furthermore, despite having fewer responsibilities in terms of historical emissions, countries in the Global South are the most vulnerable (Tuana, 2019). Similar inequalities can also be observed among social classes. Bruckner et al. (2022) recently found that the top 10% of emitters account for nearly half of all carbon dioxide (CO_2) emissions, while the bottom half of carbon emitters in the global population is responsible for only one-tenth of global carbon emissions.

Similar inequalities are reflected between territories.[1] Cities are major agents of climate change, and their role is increasing, particularly in developing countries (IPCC, 2022). There is great concern about how interactions between changing urban forms, the marginalisation of urban residents and the vulnerability of infrastructures can lead to climate change-induced risks and losses for cities and settlements. These impacts will disproportionately affect already marginalised people, including the poor, ethnic minorities, indigenous communities, and women (IPCC, 2022). However, pre-existing inequalities between cities and other territories should also be considered. For instance, Brenner and Schmid (2015) emphasized how territories of extended urbanisation are operationalised and exploited to support the everyday activities and socioeconomic dynamics of urban life. Thus, peripheral areas (urban and rural) inhabited by poor and indigenous people become sacrificial zones destined to bear the burden of the social and environmental costs associated with urban metabolism (Lerner, 2010). Despite the existence of sacrificial zones, actions to address climate crisis and phasing out fossil fuels are limited and slow. Oil extraction in remote areas and the oil consumption process entail changes that transcend the dimension of oil-related facilities and their impacts, encompassing both the spatial practices of local people and the representations of these territories contributing to what Hein (2018) called the petroleumscape. Therefore, those striving to achieve climate justice in future cities must consider the multiple relations that cross the boundaries between territories of welfare and sacrificial zones that are continuously shaped by the reproduction of petroleumscapes and the diffusion of petrocultures (Szeman, 2019).

1.2. Transformative climate Justice: citizen science and actions for climate empowerment

Regarding just futures in climate change, many authors (Newell et al., 2021; Sultana, 2021) have already pointed out the limitations of technocratic and individual-responsibility-based approaches that currently dominate climate negotiations. They argue that meaningful climate justice must incorporate the perspectives and voices of indigenous people and local communities (IPLCs). One motivation behind this assertion is that IPLCs possess valuable knowledge, which often escapes the analyses and approaches of experts. Consequently, top-down planning often creates new uncertainties and vulnerabilities, especially for poor and marginalised people, constraining their livelihood choices and narrowing pathways for socially just adaptation (Mehta et al., 2019). Another aspect to consider is the existence of different understandings and pursuits climate justice (but also of concepts such as well-being and sustainability) among pluriverses (Escobar, 2011; Kothari et al., 2019).

Sultana (2022b) emphasizes the need to consider intersectional aspects of gender, race class and indigenous aspects within climate justice to ensure equitable and contextually appropriate interventions. In addition, involving indigenous and grassroots movements is crucial to avoid climate adaptation and mitigation to reproduce the same social and institutional inequalities that led to this climate crisis (Anguelovski et al., 2019; Newell et al., 2021; Temper et al., 2020). Failure to do so may result in climate change discourses being co-opted to enact exclusionary policies. For instance, Anguelovski et al. (2016) reported that there is '*growing evidence that urban economic actors may be employing the rhetoric of climate resilience to entrench speculative, exclusionary or unsustainable practices, thus exacerbating historic injustices associated with infrastructure and land use development*' (p. 335). This kind of awareness leads some authors to define the concept of 'transformative climate justice', arguing that achieving climate justice should lead to the transformation of the root inequalities (social, economic, power, etc.) that underlie climate change (Newell et al., 2021).

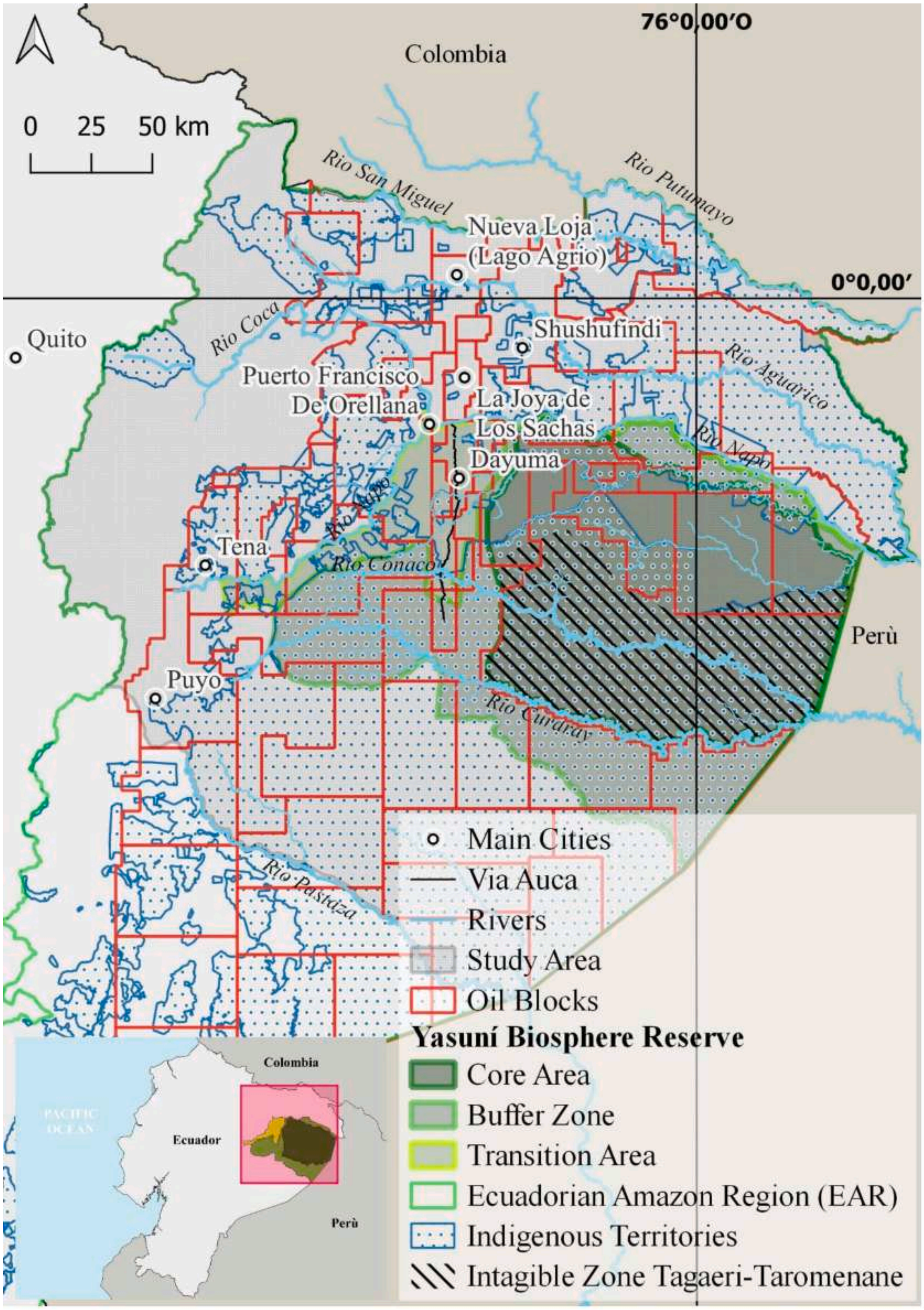
However, for impoverished people in the Global South who are accustomed to paying for the ecological costs of global social metabolism, climate change represents only the last of a long series of environmental impacts caused by actions taken for profit (Kothari et al., 2019; Martinez-Alier et al., 2014; Asamblea del Feminismo comunitario, 2010).

Notably, there is a long tradition of concepts created by grassroots organisations to protect people and the environment, such as environmental justice and environmentalism of the poor (Martinez-Alier, 2014). Climate justice can be seen as the latest descendant of this legacy, born out of the pressing need to face climate change.

In the field of geography, there is a longstanding tradition of collaboration with IPLCs to fight environmental injustices (Bacon et al., 2013; De Marchi & Diantini, 2022). Geographers have highlighted environmental degradation and the resulting inequalities, often using new geographical technologies, such as geographical information science. They have developed a vast set of approaches (Goodchild, 2007; Haklay, 2013) in which IPLCs are directly involved in the use of geographical information systems (GIS) to empower themselves. Over the past two decades, geospatial technologies have become increasingly accessible to environmental activists and IPLCs thanks to the decreased cost of access and diffusion of the open-source philosophy (Gatti & Zanoli, 2022). Hence, although the risk of de-politicisation and cooptation of these instruments to support top-down decisions is real (Radil & Anderson, 2019), GIS-based participatory approaches serve as powerful tools for academics and activists striving to shape just futures in the climate change era (Albagli & Iwama, 2022).

Finally, many scholars are actively collaborating with grassroots movements through participatory action research processes and activist scholarship to shape just futures (Albagli & Iwama, 2022; Newell & Simms, 2020; Russell, 2015; Temper et al., 2018). A notable example is the Fossil Fuel Non-Proliferation Treaty, where academics are joining citizens, states, non-governmental organisations (NGOs), local governments, indigenous communities and many other actors to implement a global strategy aimed at phasing out fossil fuels through a just and equitable transition (Newell & Simms, 2020). This cooperation between research and social movements is a key element for scaling up and scaling out the Glasgow Work Programme on Action for Climate Empowerment (ACE) issued by the Conference of the Parties 26 (COP26) aimed to empowering all members of society, including the most marginalised, to engage in climate action (United Nations Framework Convention on Climate Change, 2021). The work programme comprises six elements to be carried out (education, training, public awareness, public access to information, public participation, and international cooperation) and four thematic priority areas to consider in their implementations (policy coherence; coordinated action; tools and support; monitoring, evaluation and reporting).

[1] As theoretical basis for the notion of territory we adopted the one provided by McCall et al. (2021, pp.4).



(a)

Fig. 1. A) The ecuadorian amazon region, oil extraction, indigenous territories and protected areas; b) a gas flaring stack in the Auca oil field (Orellana province of Ecuador).

1.3. *Study area: The Ecuadorian Amazon Region*

The research focuses on the provinces of Orellana, Sucumbíos, Napo and Pastaza in the Ecuadorian Amazon Region (EAR). These are territories of recent colonization. The first attempts began in the 1950s by Christian missionaries, promptly followed by oil companies and finally farmers from other regions of Ecuador (Kimerling, 2013). Far from being the 'void land' depicted in governmental narratives and

(b)

Fig. 1. (*continued*).

policies—aimed to prompt the migration of poor farmers from the Andean and coastal regions as a source of labour for Amazonian colonisation—this area is the ancestral territory of many indigenous nationalities and a crucial hotspot for Amazonian biodiversity (Bass et al., 2010; CONFENIAE, 2022; Uquillas, 1984). Hence, the EAR is presently characterised by the operation of different and often conflicting projects aimed at natural resource management (Codato et al., 2019, Codato et al., 2022). This territorial complexity is demonstrated by the spatial overlap of the different projects, as shown in Fig. 1a, including concessions for oil extraction and protected areas such as the Yasuní Biosphere Reserve (YBR) and the Intangible Zone for uncontacted indigenous people (Tagaeri and Taromenane).

There is extensive literature regarding the socio-environmental impacts of oil extraction in the EAR (Cielo et al., 2016; Facchinelli et al., 2020; Pappalardo et al., 2013; Paz-Y-Miño et al., 2010) and the limitations of the existing regulatory framework in protecting IPLCs, as well as avoiding environmental degradation (Diantini et al., 2020; Finer et al., 2014). As a result, the EAR—the centre of a national economy based on fossil fuel extractivism (Larrea, 2017)—has become a sacrificial zone where local indigenous and *campesinos* communities bear the ecological, cultural, and social costs needed for the growth of national income consequently giving rise to various environmental conflicts (Lerner, 2010; Silveira et al., 2017).

One notable example comes from the community-based organisation the *Unión de Afectados y Afectadas por las Operaciones Petroleras de Texaco* (Union of People Affected by Texaco, UDAPT). This organisation includes and supports IPLCs in a longstanding class action suit, demanding remediation of the extensive pollution produced by the Texaco (now Chevron) oil company (Kimerling, 2013). Another case is the Yasuní Ishpingo–Tambococha–Tiputini (ITT) initiative, which was promoted by grassroots movements to leave oil underground to protect biodiversity and indigenous communities in voluntary isolation in the YBR. In 2007, the Ecuadorian government adopted and implemented the initiative, proposing an exchange for climatic benefits resulting from forest conservation, with compensation for half the potential profit loss due to leaving oil in the ground (Larrea & Warnars, 2009). Although the government's initiative failed due to a lack of international contributions and political issues, grassroots movements, including indigenous ones, continued to campaign for the protection of Yasuní by contributing to the monitoring of oil extraction and advocating for a referendum to forbid oil extraction in the area. The referendum encountered strong opposition from the government and was approved from the Constitutional Court in May 2023, following a lengthy nine-year legal battle (El Comercio, 2023; Lu et al., 2017; Moreano Venegas et al., 2021). Then, on August 20, 2023, the referendum secured victory with 58% of the votes. These conflicts can be seen as clashes between the petroleumscape (Hein, 2018) and different imagined landscapes coming from IPLCs and environmental activists that imply different ways to shape the territory, live and envisioning well-being and development.

1.4. The Apaguen los Mecheros" Campaign: When environmental and climate justice converge in sacrificial zones

Building upon the long history of environmental conflict in the EAR, the Apaguen los Mecheros (shut-off gas flaring [GF] stacks) campaign emerged in 2018 as a network of national and international NGOs, indigenous organisations, and civil society sectors (Clínica Ambiental, 2019)

The campaign aims to end GF activities in the EAR with the purpose of safeguarding numerous indigenous and peasant families while advancing climate change mitigation efforts (Clínica Ambiental, 2019). Notably, oil-related GF emissions in Ecuador amount to approximately 1

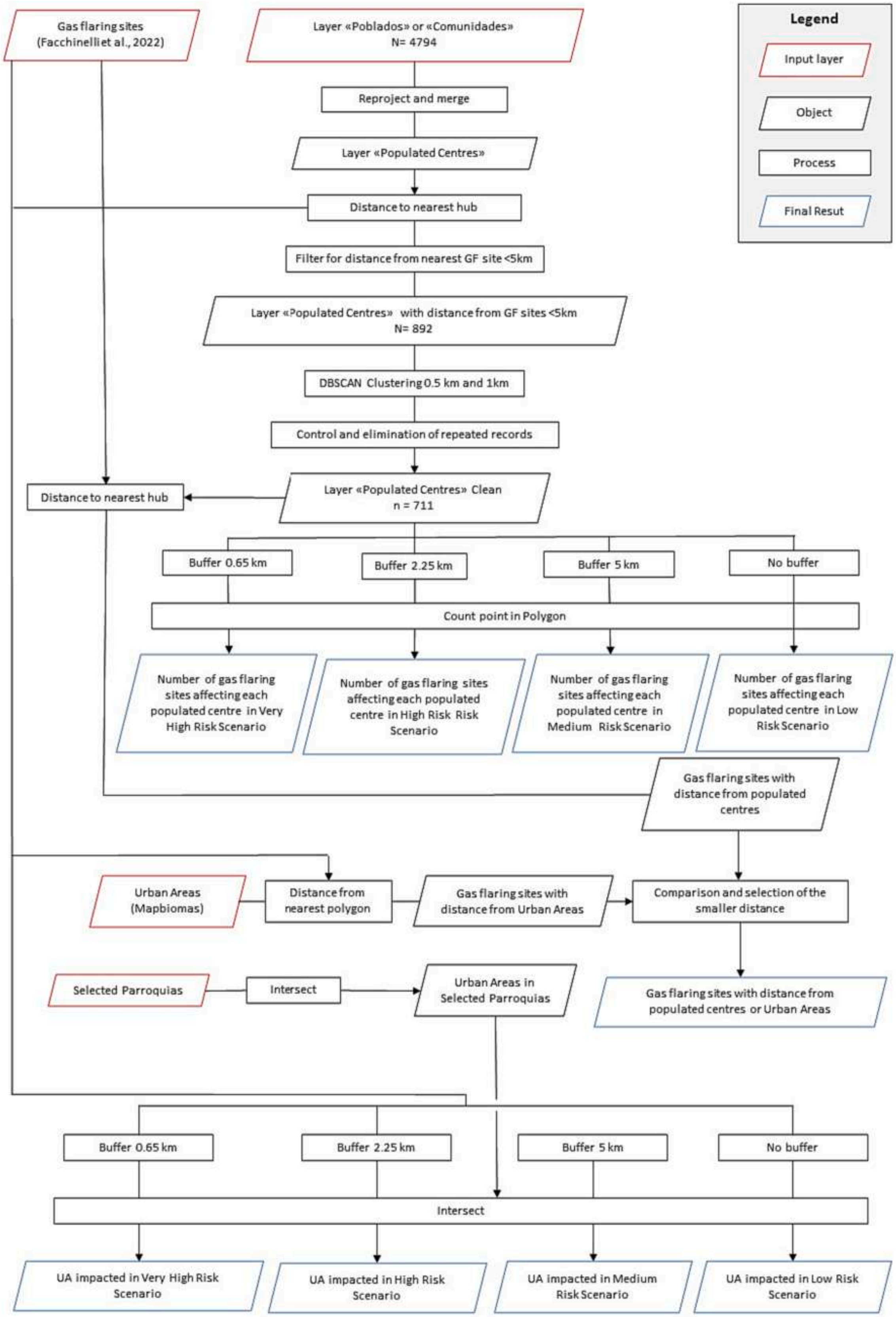


Fig. 2. Workflow of the data elaboration process.

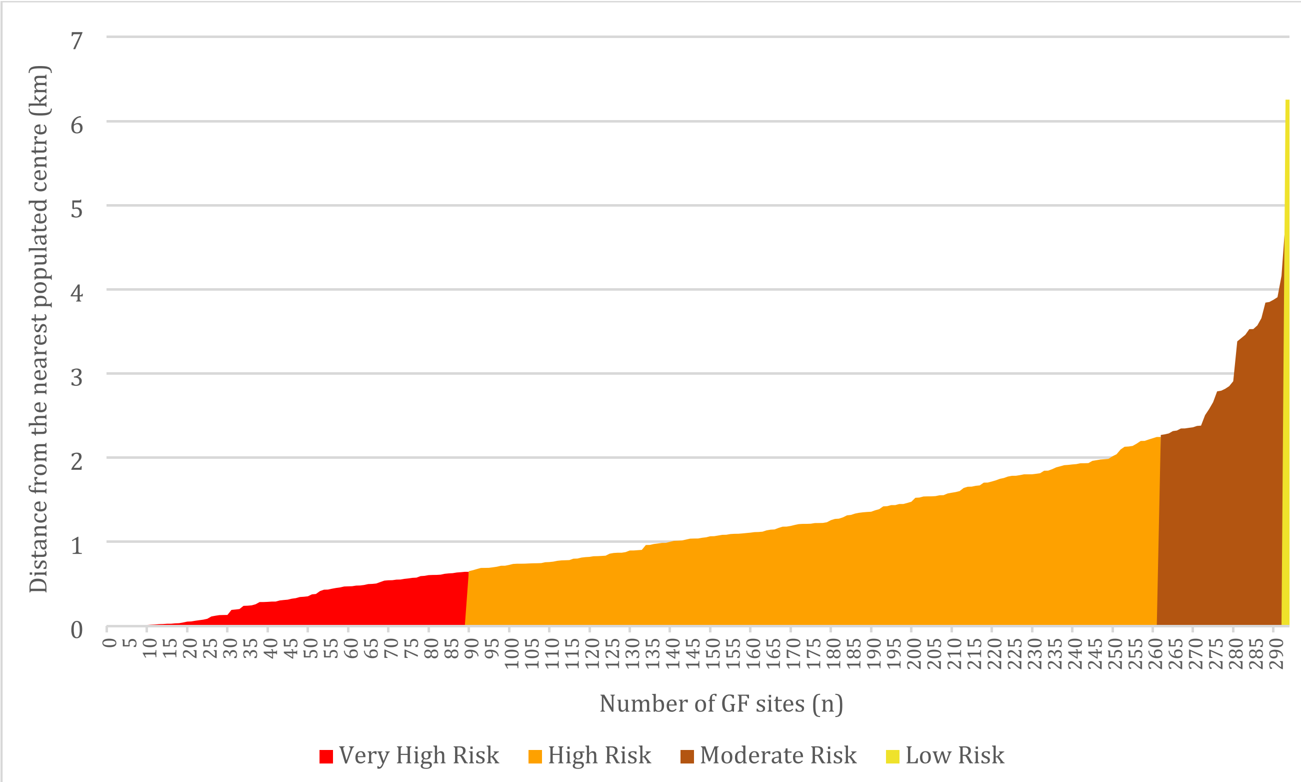


Fig. 3. Gas flaring sites that should be closed, considering the different distances from populated centres. The different colours represent different risk scenarios and the associated metrics: Very High Risk (0.65 km), High Risk (2.25 km), Moderate Risk (5 km) and Low Risk (>5 km).

billion cubic meter of methane (1800 kt of $CO_{2\ eq}$) every year, comprising 8% of Ecuador's target emission reduction, as agreed upon by the Paris Climate Agreement (Elvidge et al., 2018).

This perspective represents an important milestone for these organisations. After more than 30 years of ongoing environmental conflicts focused on demanding remediation and compensation for the socio-environmental impacts of the oil industry while protecting the Amazon rainforest, they were now also demanding meaningful action to reduce greenhouse gas emissions. This put them on common ground with many other IPLCs in sacrificial areas for fossil fuel production around the world that, while struggling for a cleaner and healthier environment, had begun to develop increasing awareness of the global impacts of climate change and the crucial role they can play in the shift towards a more climate-just world (Schlosberg & Collins, 2014; Widener, 2013).

In 2019, a participatory mapping process of all GF sites in the Ecuadorian Amazon was initiated by members of the campaign, local communities, and our research group (Facchinelli et al., 2022) by adopting an Extreme Citizen Science approach (Haklay, 2013).[2] Combining of open-source geotechnologies and indigenous and local knowledge resulted in the first ever mapping of almost 300 GF sites and 437 stacks, which came to 115 more sites than reported by the Environmental Ministry of Ecuador and 223 more than seen on satellite imagery (Elvidge et al., 2013; Facchinelli et al., 2022). An example of a GF stack (locally referred as *mechero*) can be seen in Fig. 1b.

These data were included as technical information supporting a 'Protective Action' led by nine Amazonian children calling for a moratorium on GF sites. On 26 January 2021, the Court of Nueva Loja issued a historical ruling banning GF activity in the EAR (El Universo, 2021; Facchinelli et al., 2022).

However, the ruling orders oil companies to 'close all GF sites that are near populated centres within 18 months since the issuance of the judgment, and within 2030 for the remaining ones' (El Universo, 2021).

The wording of the ruling leaves room for widely different applications. This ambiguity arises from the lack of clear criteria to identify which sites should be closed by March 2023 and 2030. Specifically, it is unclear i) what constitutes a 'populated centre' in a context where small indigenous communities are widespread and ii) what distance qualifies as 'near' when there is almost no literature reporting context-specific metrics of the socio-environmental impacts of GF activities. Furthermore, the 2030 term simply confirms Ecuador's commitments, as taken under the World Bank's Global Gas Flaring Reduction Partnership (The World Bank, 2013).

Finally, on 28 March 2023, during the judicial hearing to verify the ongoing process, the Ministry of Energy and Mines of Ecuador approved a regulation that arbitrarily defined these concepts and proceeded to shut-off 112 GF sites. However, no analyses conducted to identify the closed GF sites were provided, which is currently a point of debate in the implementation of the ruling (El Universo, 2023).

1.5. Objectives

This study aims to generate various health risk scenarios to support the implementation of the ban issued by the Court of Nueva Loja regarding GF activities. The specific objectives are to i) identify which GF sites should be closed according to the judgement, ii) estimate the populated centres in the EAR that are affected by GF activities and iii) estimate the impact of ongoing GF activities on the four main urban agglomerations in the EAR. The objectives are framed in the Extreme Citizen Science process carried out by the Apaguen los Mecheros campaign.

[2] For more details on the participatory process, as well as on the Extreme Citizen Science approach adopted, see Facchinelli et al., 2022.

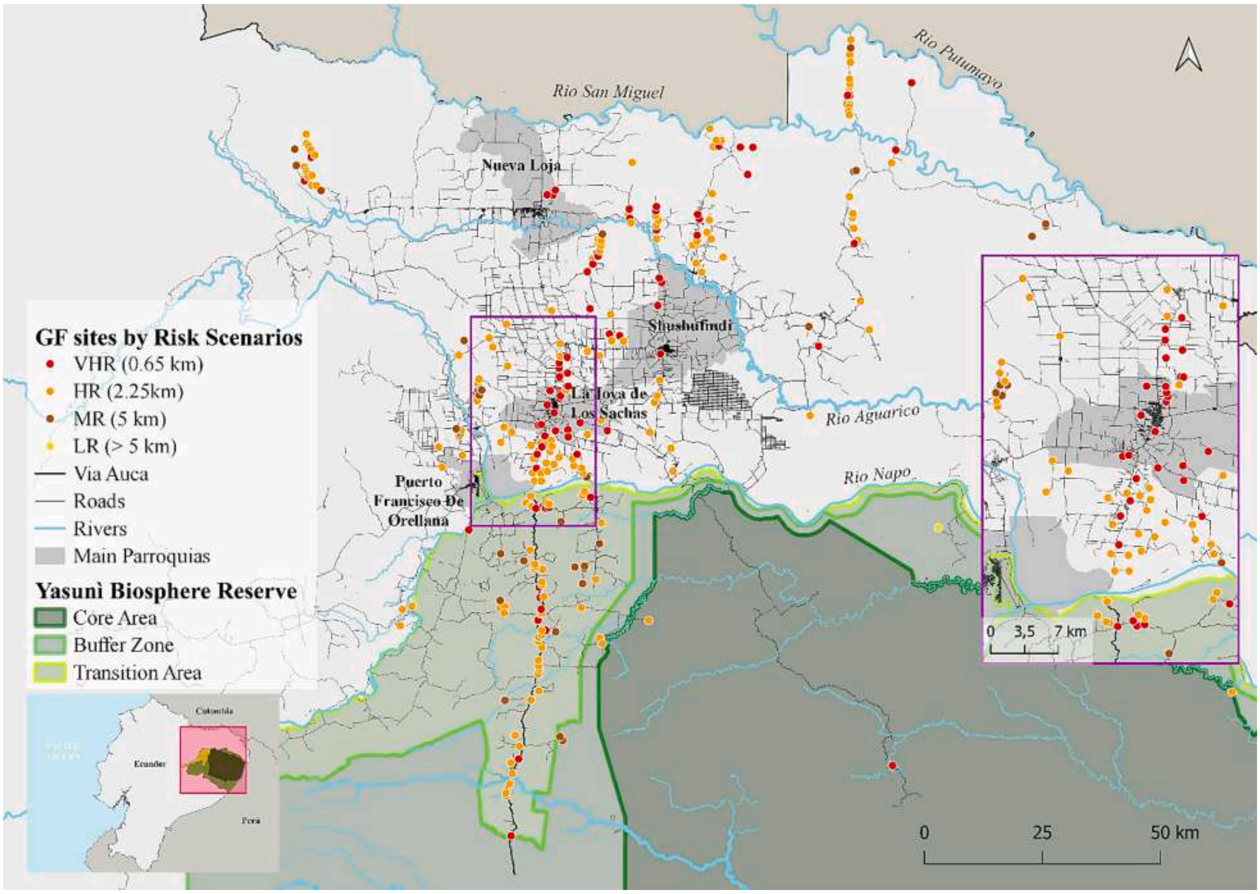


Fig. 4. Map of gas flaring (GF) sites that should be closed according to different risk scenarios and the associated metrics: Very High Risk (0.65 km), High Risk (2.25 km), Moderate Risk (5 km) and Low Risk (>5 km).

2. Materials and methods

2.1. Data

Four types of data were used in this analysis: GF sites, the location of populated centres, data on administrative boundaries and demographic information of the so-called '*parroquias*' (an administrative unit in Ecuador equivalent to a parish) and data on urban areas.

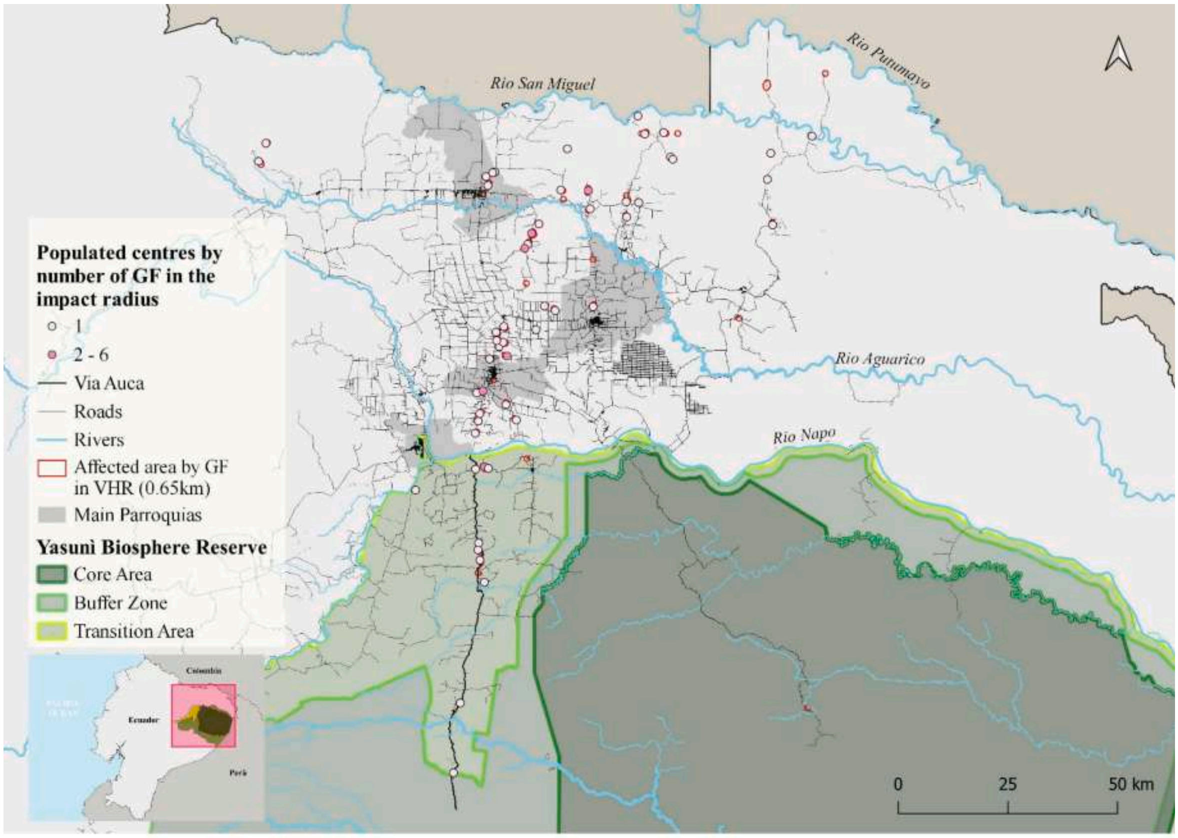
For GF facilities in the region, we relied on the datasets generated by Facchinelli et al. (2022) due to their demonstrated reliability and comprehensiveness compared to other sources, including satellite monitoring or data from the Ministry of Environment. The datasets include 295 sites (totalling 437 stacks) and are freely accessible online (Amazonya Project, 2020).

The data regarding populated centres were sourced from various Ecuadorian institutional bodies, including the Gobierno Autónomo Descentralizado de la provincia de Sucumbíos and the Geographical Military Institute (Instituto Geográfico Militar [IGM]). In the first case, the data were retrieved directly at Gobierno Autónomo Decentralizado headquarters, and in the second case, they were retrieved from the appropriate geoportal and Web Feature Service using data named *poblados* (settlements) and *comunidades* (communities) (IGM, 2017). We included the *comunidades* layer, which refers mainly to indigenous communities, as the Marco Maestro de Muestreo of the Instituto Nacional de Estadística y Censos (INEC) of Ecuador defines *populated centres* as 'any place in the national territory, rural or urban, identified by a name and inhabited on a permanent basis. Its inhabitants are linked by common economic, social, cultural and historical characteristics' (INEC, 2010). Furthermore, the same document classified populated centres as urban or rural, depending on whether the number of inhabitants exceeded 2,000 people, in order to include smaller settlements. The dataset derived from this information comprised 61 layers, 44 of which were related to settlements and 17 of which were related to communities, for a total of 4,794 points, including 4,319 populated centres and 475 communities.

To assess the risk posed from GF activities in the areas with more concentrated and consolidated urban texture in the northern EAR we selected the following cities: Nueva Loja (Lago Agrio), Shushufindi, Puerto Francisco De Orellana (El Coca) and La Joya de Los Sachas (Cabrera-Barona et al., 2020; González-Comín, 2023). Notably, 47% of the population of the provinces of Orellana and Sucumbíos reside in one of the above-mentioned *parroquias*, corresponding to 147,200 people (INEC, 2010). Data on the administrative boundaries of the *parroquias* were retrieved from IGM (2017), while data on the population of the *parroquias* were retrieved from INEC (2010). As the data from the IGM (updated in 2013) did not reflect the current state of urban expansion, we opted to utilize land cover data from the Amazonias Mapbiomas project carried out by the Amazon Network of Georeferenced Socio-Environmental Information, which provides updated data regarding land cover in the Amazon based on Landsat imagery (Proyecto Map-Biomas Amazonía, 2020).

2.2. Metrics on spatial impacts of gas flaring sites to define health risk scenarios

To define the health risk scenarios, the work of Facchinelli et al. (2020) was referenced. Following a literature review, they reported eight studies showing the areal impacts of GF activities, with distance values ranging from 0.650 km to 5 km. Additionally, we incorporated other relevant literature that investigated the effects of GF activities on



(a)

Fig. 5. Map of populated centres by number of gas flaring (GF) sites in the range of potential impact in the different scenarios: a) Very High Risk, based on 0.65 km of impact; b) High Risk, based on 2.25 km of impact; c) Moderate Risk, based on 5 km of impact; d) graph reporting for each risk scenario for the populated centres by number of GF sites affecting them and the ratio between populated centres affected and GF sites that should be eliminated.

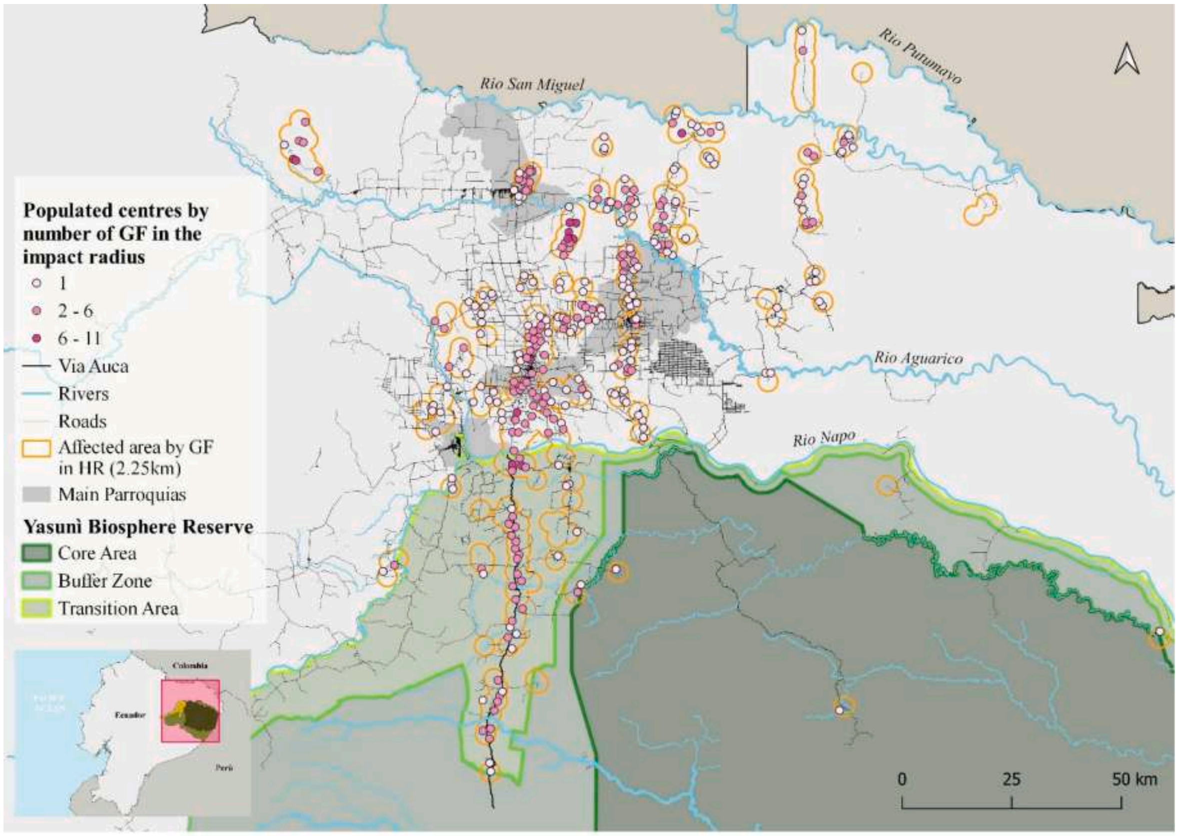
human health. This included research reporting concentrations in the air of particulate matter 2.5, nitrogen oxides and carbon monoxide above the World Health Organisation's guidelines at 3 km from the GF stack (Giwa et al., 2019); alterations of haematological parameters at a distance of 2 km (Adienbo & Nwafor, 2010); and negative correlation between birth outcomes and the presence of GF activities within a 5 km radius (Cushing et al., 2020). Therefore, the maximum, minimum and average values were used to create three different health scenarios identified as: very high-risk (VHR) within 0.65 km, high-risk (HR) within 2.25 km and moderate-risk (MR) within 5 km. As some studies underscore a more extended spatial dimension regarding the contamination related to GF activities, particularly in cases in which the activity is continuous over the years, areas located more than 5 km from GF sites were considered low-risk (LR) (Amadi, 2014; Anejionu et al., 2015). However, due to the complexity of quantifying possible impacts, the LR was included only in the analysis of GF sites that should be closed according to the court judgement.

2.3. Spatial analyses

This study employed a geodatabase to organize the data, which was then imported into QGIS version (version 3.12). The reference system used was WGS 84 / UTM zone 18S EPSG 32718, allowing for the reprojection of data from different reference systems (Fig. 2). To perform a preliminary analysis, all layers related to populated centres were merged, filtered based on a 5-km radius from GF sites. Duplicates were checked and removed. In the cleaning phase, all populated centres with less than 0.5 km between each other (1 km if their names matched) were considered the same, and the centroid was considered. This process resulted in the elimination of 181 points.

To identify which GF sites should be closed in each scenario, a proximity analysis was conducted using the cleaned dataset on populated centres (see Section 2.1) and the urban areas from the Amazonias Mapbiomas project. The distance with the nearest element was considered and used to categorise the GF site according to the different scenarios (see Section 2.2).

To estimate the number of GF sites affecting each populated centre according to the different scenarios, the cleaned layer on populated centres was used to create buffers corresponding to each scenario's distance (0.65 km, 2.25 km and 5 km). The 'Count points in polygon' algorithm was then employed to determine the number of GF sites affecting each populated centre. To assess the potential impacts on the urban populations of the four major Amazonian cities, our methodology involved several steps. First, we identified urban areas within the administrative boundaries of the corresponding *parroquias* (administrative divisions). Next, we calculated the intersections between these urban areas and buffer zones created at distances of 0.65 km, 2.25 km, and 5 km from the GF sites, which served as reference points. The resulting layer depicted the impacted sections of the urban areas within each scenario. Consequently, assuming that the percentage of the affected urban area (in relation to the total urban area in the parroquia) was indicative the proportion of affected population (relative to the total residents in the parroquia), we were able to estimate the number of residents impacted by the proposed scenarios.



(b)

Fig. 5. (*continued*).

3. Results

3.1. Analysis of GF sites that should be closed

According to the current literature and available data, the results of the proximity analysis of GF sites and populated centres suggest that there are almost no GF sites in the EAR that do not put local populations health at risk (Fig. 3). Notably, in the MR, it is recommended that 294 of the 295 sites should be closed. Moreover, in the VHR, 90 GF sites (31% of the total) affect at least one populated centre and should thus be closed, while in the HR, 262 sites (89% of the total) should be shut off. Fig. 4 provides the geographical distribution of the GF sites that should be closed according to different health scenarios. The HR scenario reveals clustering of GF sites, particularly around La Joya de Los Sachas and Nueva Loja, as well as in the central and northern parts of Via Auca, which is the main oil road entering the YBR from Puerto Francisco De Orellana. These areas highlight the locations where local populations may face increased exposure. The HR scenario confirms these hotspots and shows additional clusters compared to the VHR scenario, such as to the north of Shushufindi, as well as a more widely distributed pattern. The site included only in the LR is located in oil block 12 (also known as Eden Yuturi) and in the buffer area of the YBR (see Fig. 4)—an area where 'cooperative activities compatible with sound ecological practices, including environmental education, recreation, ecotourism and applied and basic research' should be developed (UNESCO, 1989).

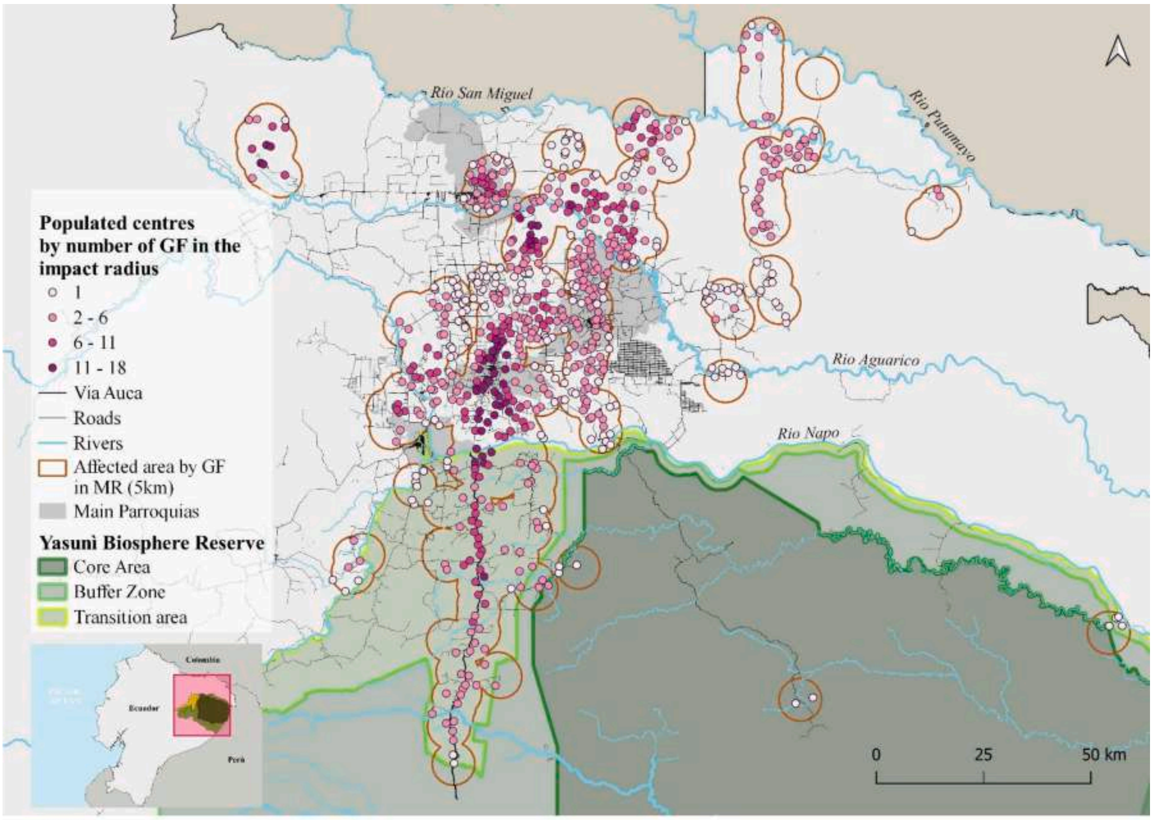
3.2. Analysis of corresponding impacts on local communities and populated centres

Fig. 5a illustrates the distribution of populated centres affected by GF activities in the VHR, with a total of 55 populated centres within the affected area. Within a 0.65-km radius, there are six locations with multiple GF sites. The most heavily impacted area is located in the southern part of the La Joya de Los Sachas parroquia, which has four GF sites. In the HR, shown in Fig. 5b, it is estimated that 318 populated centres are affected by at least one extra GF site. The populated centres in the most affected category (5–10 GF sites in a 2.25-km radius) are mainly concentrated near Nueva Loja in the southeast section.

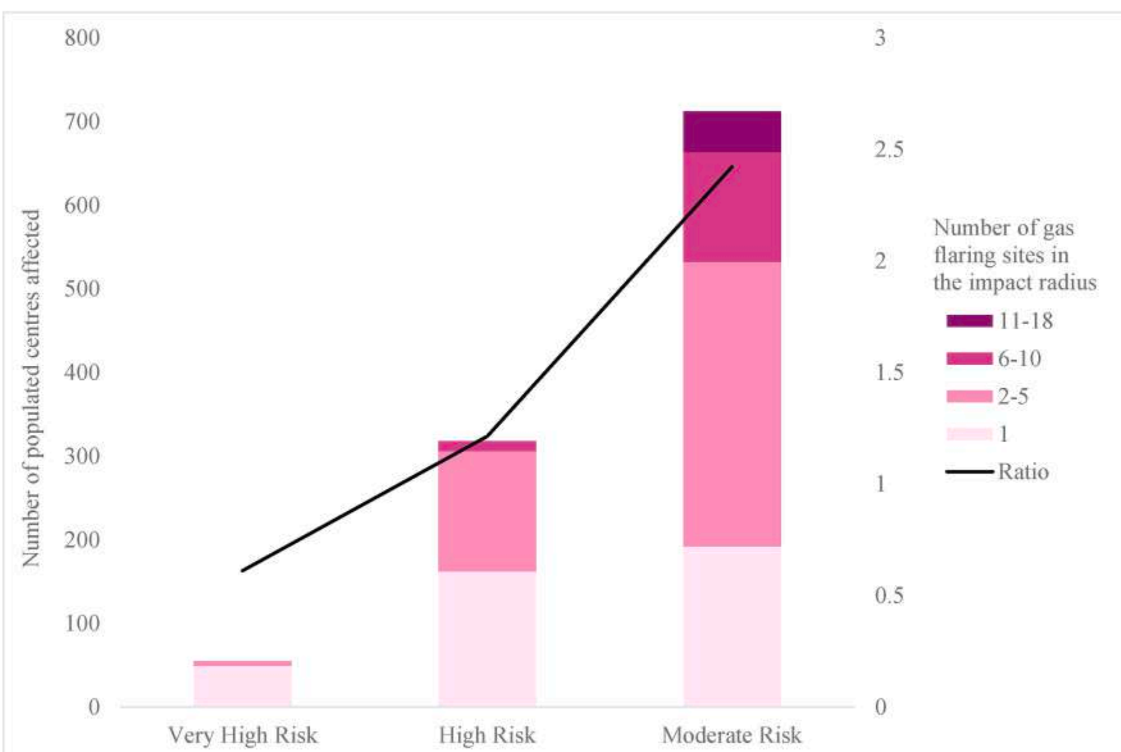
Fig. 5c displays the MR, where the affected populated centres are more widely distributed and have many different clusters. The 49 centres in the most affected category (where 10–18 GF sites are found within a 5-km radius) are mainly concentrated in 3 clusters: La Joya de Los Sachas, the area immediately southeast of Nueva Loja and the northern part of Via Auca.

The number of populated centres affected by multiple GF sites increased proportionally when the impact distance was considered (with 'less risky' scenarios), reaching 156 sites (45% of the affected) in the HR and 520 (73% of the affected) in the MR, as shown in Fig. 5d. Additionally, the ratio of affected populated centres and GF sites increases from 0.6 in the VHR to 1.2 in the HR and 2.4 in the MR. Hence, while the VHR highlights areas where the health risk is due to the proximity of a single GF site, the other scenarios emphasize regions that may experience less intense but more dispersed pollution resulting from the cumulative effects of various stacks. This is particularly true for populated centres simultaneously affected by 2–5 or 6–10 GF sites in the HR and 6–10 or 11–18 sites in the MR.

Finally, comparing the different maps (Fig. 5 a, b and c) shows that some populated centres in the VHR pertain to the most affected categories in the HR and MR due to the elevated proximity to GF activities and the presence of multiple sites.



(c)



(d)

Fig. 5. (*continued*).

Table 1
Estimation of gas flaring activity impact on four main urban areas in the Northern Ecuadorian Amazon.

	Total		Very High Risk		High Risk		Moderate Risk	
	Urban area (km^2)	People (n)	Area (%)	People (n)	Area (%)	People (n)	Area (%)	People (n)
La Joya de Los Sachas	9.6	17,934	20.1	3,607	95.1	17,068	99.6	17,865
Nueva Loja	23.3	57,727	9.8	5,657	51.1	29,511	86.1	49,690
Puerto Francisco De Orellana	18.6	45,163	0.1	39	0.1	48	12.2	5,521
Shushufindi	11.0	26,376	10.7	2,814	68.4	18,064	96.0	25,315
Total	62.5	147,200	8.6	12,718	45.7	67,312	67.9	99,918

3.3. Analyses under different scenarios of overlap between estimated impact and Amazonian urban areas

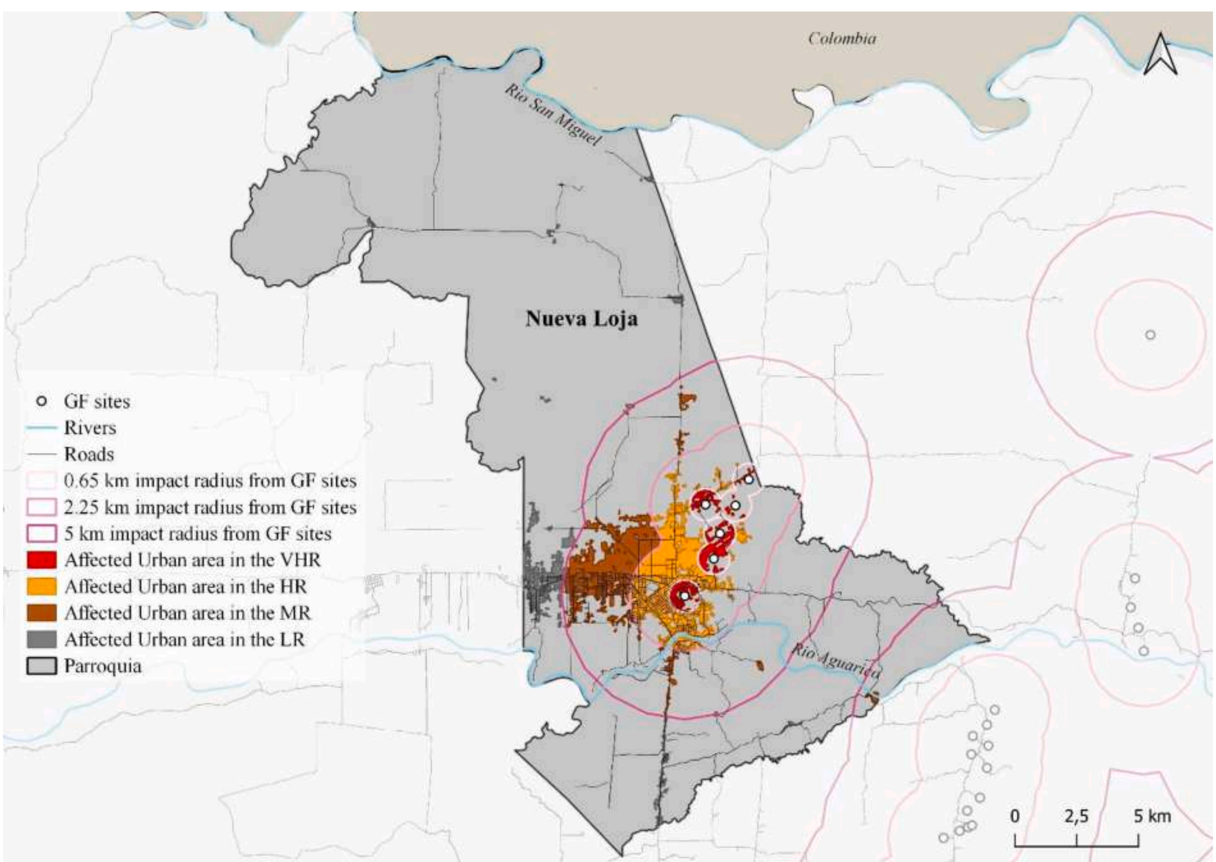
The estimation of the impact of GF activities on the four main cities in Northern Ecuadorian Amazon shows that, although there are notable differences between different areas, 67.9% of the overall population (~100,000 people) in the MR is affected by GF activities (see Table 1 and Fig. 6). There are 12,718 people in VHR areas (8.6% overall) and 67,312 people (45.7% overall) in HR areas.

Among the four cities, Nueva Loja is the most heavily impacted in all scenarios. This is primarily due to its large population, making it the most populous city among the four, as well as the presence of GF sites embedded within urban areas (Fig. 6a). Despite only 9.8% of its urban area being affected by the VHR, this amounts to 5,657 people, or about 45% of the total population affected. In the other scenarios, the situation escalates, reaching 29,511 people affected in the HR and 49,960 people affected in the MR.

La Joya de Los Sachas has most of its urban areas falling within the HR (95.1%) or the MR (99.6%), while a substantial amount (20.1%) is in the VHR. This is partly due to its smaller dimension in comparison to the other cities but also to the extreme proximity of oil fields with active GF sites.

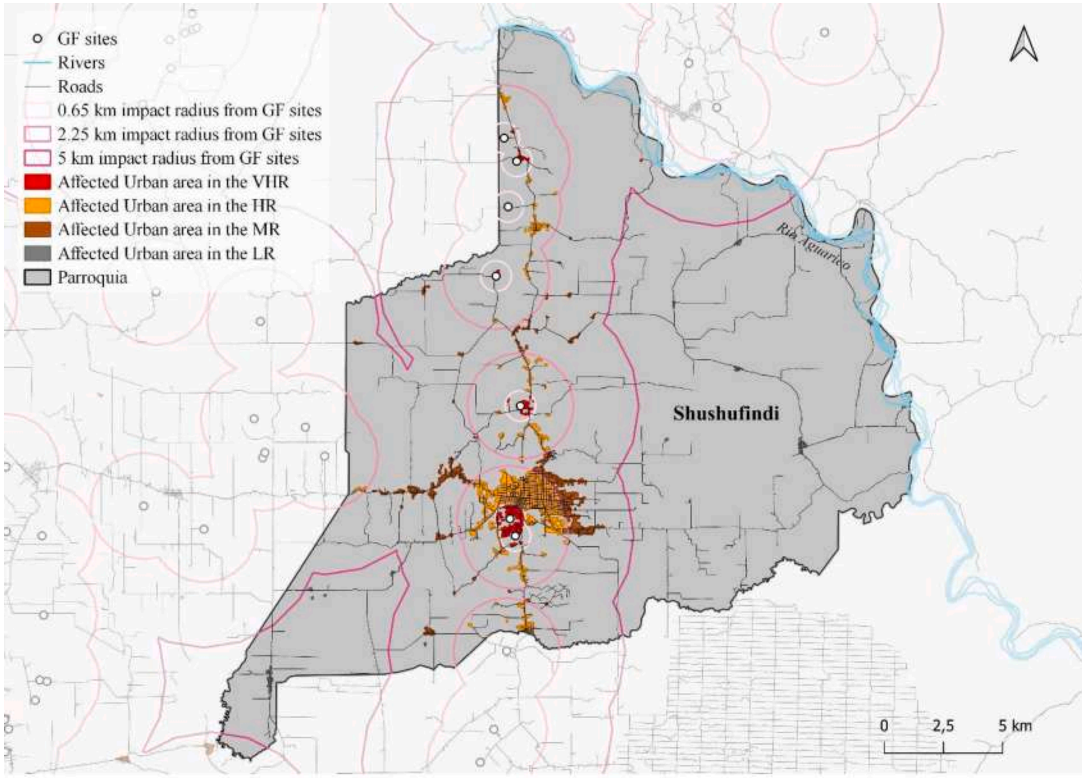
In Shushufindi, affected areas are mainly related to an oil refinery located on the city's border. Although the number of affected people is smaller than in Nueva Loja (2,814 people in the VHR, 18,064 in the HR and 25,315 in the MR), the percentages of affected areas are higher, reaching 96% in the MR.

Finally, Puerto Francisco De Orellana presents a relatively better situation thanks to few GF sites being in its proximity, ranging from 0.1% of affected areas in the VHR and HR to 12.2% in the MR. However, due to the high population density in the city, the MR scenario still affects 5,521 people.

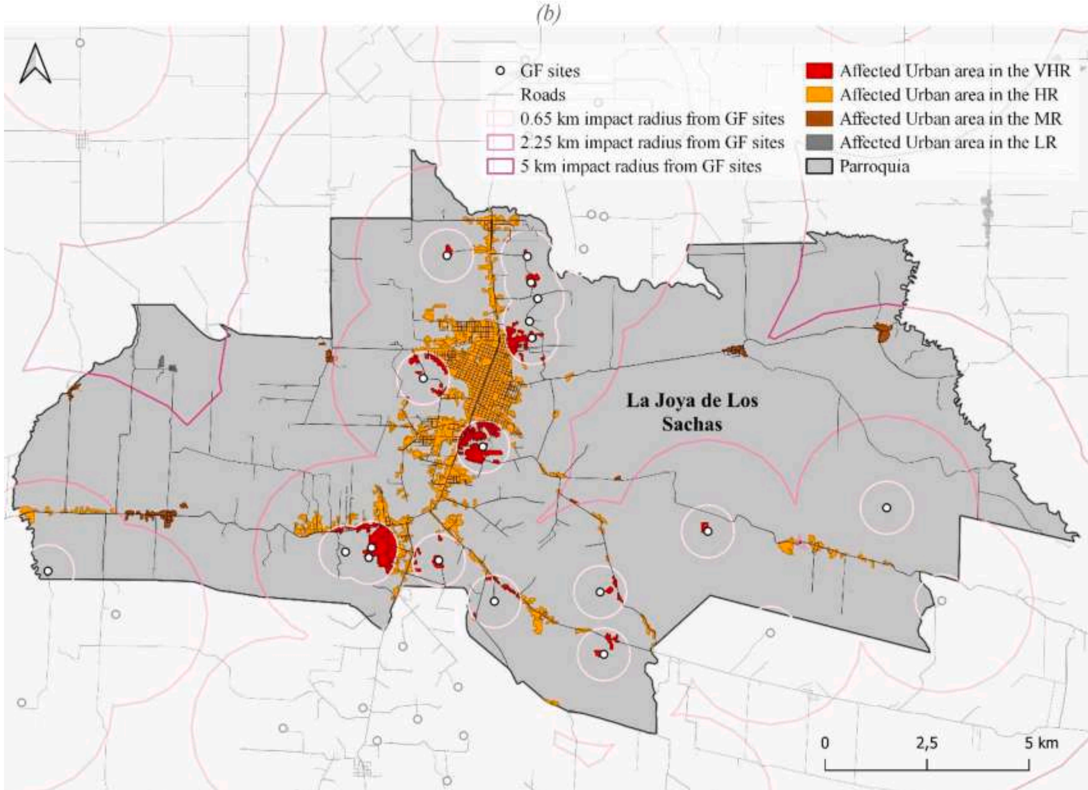


(a)

Fig. 6. Potentially affected areas in four main urban areas with oil extraction in the Northern Ecuadorian Amazon: a) Nueva Loja; b) Shushufindi; c) La Joya de Los Sachas; and d) Puerto Francisco De Orellana.

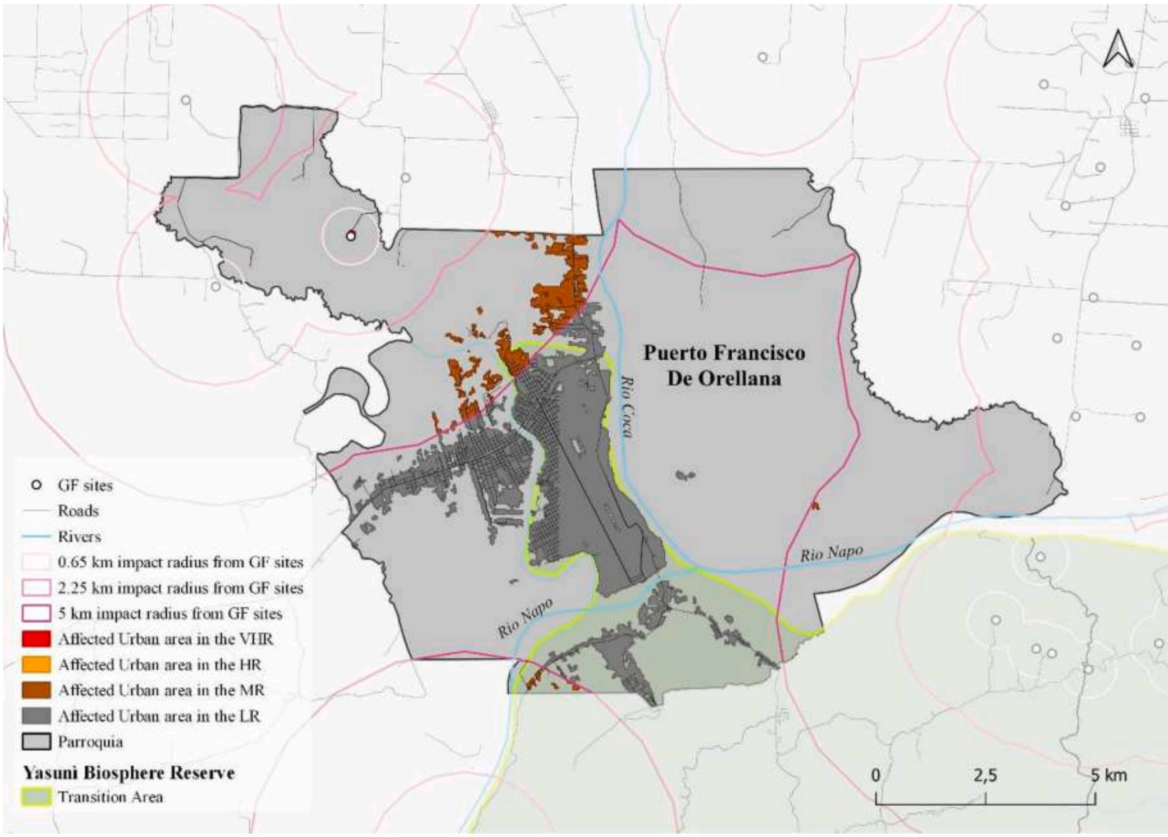


(b)



(c)

Fig. 6. (*continued*).



(d)

Fig. 6. (*continued*).

4. Discussion

By reporting on the recent developments of the campaign Apaguen los Mecheros aimed at banning GF activities in the EAR, the present research highlights how people living in sacrificial zones are not only targets of climate change but also active actors in the creation of just futures (Temper et al., 2020). Engaging IPLCs to assume a central role for driving policy change is also about truly putting ACE into practice by applying Article 12 the Paris Agreement and the Glasgow Work Programme on ACE issued by COP26, which call to promote public participation and public access to data and information that enables everyone "to understand, address and respond to climate change" (United Nations Framework Convention on Climate Change, 2021).

This study provides the first assessment of potential health risks due to GF activities in the EAR, utilizing spatial proximity as a key factor. Despite the lack of context-specific data the present study offers an overview of the spatial relation between GF activities and IPLC settlements, highlighting the implications of some tentative distances of impact based on existing literature in other contexts. Notably, although the ruling mandated the designated ministries to conduct analyses on the impacts of GF activities, compliance with this requirement has been lacking.

The findings of this study demonstrate that the vast majority of GF sites in the MR (294 out of 295) pose a threat to the health of IPLCs and at least one populated centre, thereby requiring their closure in accordance with the Court of Nueva Loja's ruling. These results provide useful data to support the application of the ban on GF activities in the EAR and were utilized by campaign members during the debate with the judge and the ministries on which GF sites should be closed within the 18-month deadline. This confirms the significant role of academic activism and participatory processes in democratizing access to scientific knowledge and ensuring the right to environmental monitoring, as guaranteed by the Escazú Agreement in Latin America (Albagli & Iwama, 2022; United Nations, 2018). An intriguing discussion arises from the fact that the only GF site not affecting a populated centre is located in the buffer zone of the Yasuní Biosphere Reserve (YBR). This is particularly significant when considering the explicit recognition of nature's rights in the Ecuadorian constitution, the ecological importance of the Ecuadorian Amazon as a biodiversity hotspot within the Amazon Rainforest, and the recent referendum to leave oil underground in the Yasuní area to protect ecosystems and indigenous populations on a global scale (Bass et al., 2010; El Comercio, 2023; Larrea & Warnars, 2009; Republic of Ecuador, 2008).

The MR—where 520 of the populated centres are affected by 2–18 GF sites—suggests that these scenarios should not be regarded as mutually exclusive but rather as representations of overlapping forms of contamination. This finding aligns with previous studies that highlight how pollution from long-term GF activity may have a much wider scale (Amadi, 2014; Anejionu et al., 2015). These results also show how the closure of 112 GF sites declared by the Ministry of Energy and Mines may not be enough to ensure the health safety of Amazonian IPLCs.

The city with the highest percentage of people affected is La Joya de Los Sachas (20%, 95% and 99% for VHR, HR and MR, respectively). Nueva Loja has the highest number of people potentially affected in all scenarios, accounting for about 45% overall. In the most contaminated cities, spatial proximity of GF sites to inhabited areas represents a key factor in increasing the number of impacted people. This threat is deeply rooted in the historical development of these urban centres, which were often established around key areas of oil extraction or processing (Wilson et al., 2015). Considering how the health of 12,718–99,918 people may be affected by GF activities, the results oppose the petroleumscape narrative, that portrays oil extraction as a source of progress and well-being for local populations (Hein, 2018). This discourse has been entangled with oil extraction in the EAR since its inception (Kimerling, 2013) and later adopted from progressive governments to enact neo-extractivist policies under the banner of the need to provide resources to fight poverty and achieve national development (Gudynas, 2012). However, these visions share the willingness to make these territories a sacrificial zone for the support of national and global economies and have been strongly contested from social movements (Silveira et al., 2017).

5. Conclusions

People living in sacrificial zones for fossil fuel extraction can play a key role in prompting policy change toward climate justice. Participatory research involving academic activism and IPLCs can support this process by enabling access to knowledge co-production. This study provides the first assessment of the risk posed to the health of Amazonian IPLCs from GF activities. In doing so it supports the campaign Apaguen los Mecheros by informing the application of the ruling from the Court of Nueva Loja regarding the ban on GF activities in the EAR. We elaborated risk scenarios for human health by geoprocessing spatial data on GF sites and populated centres with different spatial metrics available in the literature on GF impacts. Results underline that almost all GF activities are near enough to pose a threat to at least one populated centre. The presence of 180 populated centres affected from up to 6–18 sites in the MR, suggests that the cumulative impact from multiple sources should be considered. Consequently, the different scenarios should be interpreted not as mutually exclusive but as overlapping layers of concentrated and dispersed contamination.

This study is a starting point for directing further analyses that are needed to accurately assess the impacts of GF on Amazonian communities. Further research is needed to better understand GF impacts in the Ecuadorian Amazon region, which may focus on: i) collecting context-based data to more accurately assess the influence areas posing risks to human health by GF sites, ii) investigating the cumulative impacts and the synergies produced in those areas affected simultaneously by multiple GF.

Data availability

The data produced can be accessed at: https://www.climate-justice.earth/impacts-of-gas-flaring-activities-on-populated-centres-and-urban-areas-in-the-ecuadorian-amazon-region/.

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.

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