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The multiple injustice of fossil fuel territories in the Ecuadorian Amazon: Oil development, urban growth, and climate justice perspectives

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HIGHLIGHTS

- Urban expansion in Ecuadorian Amazon Region (EAR) is mainly linked to oil activities.
- So far, exploited oil blocks showed higher urban infrastructures than the rest.
- Indigenous territories are surrounded by urban infrastructure, as oil exploited areas.
- Oil spills, pits and gas flaring are recorded in historically exploited oil blocks.
- EAR multiple injustice: an unhealthy environment and few benefits from oil revenues.

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ABSTRACT

Alongside growing awareness of the historical and ethical dimensions of climate change impacts, little is known about those territories both sources of fossil fuel extraction as well as not beneficiaries of its benefits, usually located in developing countries. Our study frames climate justice in the Ecuadorian Amazon Region (EAR), defined as "urban jungle", due to urbanization processes linked to oil exploitation. By highlighting the multiple injustices for local communities, the general aim is showing how these areas are at the same time peripheries of fossil fuel extraction and national benefits, while also being entangled with the socio-environmental impacts caused and increased by oil activities. The methodology is based on spatial analysis carried out in GIS environment, combining different features (oil production, urban infrastructure, socio-environmental impacts), at different spatial and temporal scales. Results show that, since the beginning of oil exploitation in 1972 and until 2020, about 6.4 billion barrels were produced in the EAR, in 34 oil blocks located in the central-north sector. Moreover, between 1985 and 2020, oil exploited EAR has continued to be the most urbanized part, surrounding and involving indigenous territories and ethnic population in voluntary isolation. Finally, the results highlight the high density of recorded oil spills, pits and gas flaring sites in historically exploited oil block, and the extensive distribution of seismic lines in all the EAR, far from human rights obligations of enjoying a safe, clean, healthy and sustainable environment. In conclusion, our analyses highlight the multiple injustices of these territories. Hence climate justice should embrace these territories in its perspectives, by involving them in the climate justice discourse and promoting the rights for a non-toxic environment. By doing so, scholars, stakeholders and policymakers might frame clear and just phasing out fossil fuel strategies.

1. Introduction

1.1. Fossil territories and climate justice in the Global South

The concept of climate justice points to the international and intersectional inequities due to climate change causes and impacts (Goodman, 2010; Knox, 2018; Porter et al., 2020).

Climate justice considers climate change as a double source of inequality and it separates the world population into two wide dimensions (Porter et al., 2020). The first encompasses countries, corporates, citizens, and communities that took advantage of fossil fuel economic development. Usually, this dimension denotes developed countries, and it involves those that have mostly generated the negative impacts of climate change. Moreover, within such framework, countries

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usually have the capability and skills to mitigate and adapt to climate change by their own economic resources and technology development. The second dimension is generally represented by disadvantaged populations, mainly those located in developing countries. This group usually gains little benefit from fossil economic development, and it has been exploited for economic development by developed countries while also having little historical responsibilities in greenhouse gases (GHGs) emissions and climate change effects. This dimension usually suffers disproportionate impacts caused by climate change and pollution because of a lack of resources to mitigate and adapt to its effects. Moreover, in these territories, global warming impacts tend to compound and exacerbate the present inequalities and injustices (Füssel, 2010; Porter et al., 2020). These dimensions are not "fixed" nor static but can vary between and within the countries and during the time (Bruckner et al., 2022). For example, in recent years, some developing countries, in particular India and China, dramatically increased GHG emissions, passing historical polluters such as the UK, highlighting the presence of injustice also within the same country, where a small part of the population or corporations is responsible for most parts of the pollution and have the resources to cope with climate change impacts (Newell & Simms, 2020).

In this framework, climate justice concepts are also fundamental to dealing with the injustices taking place in the fossil fuels supply side areas of the world.

However, little is known about those territories and communities that are both sources of fossil fuel extraction and located in developing countries, for example, Maracaibo (Venezuela) or Port Harcourt (Nigeria), where capitals, decisions, and most of the benefits are in the hand of few international oil companies from developed countries or of national enterprises located in the richest part of the country (Muttitt & Kartha, 2020). In these countries, extraction and mining could be essential for Gross National Income, for employment or could also cover a crucial political and cultural role (Carley et al., 2018). As reported by Muttitt and Kartha (2020), on the one hand, fossil fuel extraction could provide some benefits such as jobs, energy, and revenues; on the other hand, it is also a source of pollution, corruption, and inequalities (Kartha et al., 2016).

Another important issue related to these territories and countries is the process of phasing out from fossil fuel extraction. Indeed, a rapid energy transition is fundamental for avoiding the worst dangers of climate change. However, a more in-depth focus should be provided on analyzing the relations between country/local territories in which fossil fuel operations create an increase of National Income against local toxic environments and sacrifice zones[1] (HRC, 2022; Lerner, 2010).

This is our case study: the Ecuadorian Amazon Region (EAR), where the productivity of fossil fuel is at high levels and where a large part of National Growth was built on this activity.

1.2. Urban jungle and Amazon rainforest

The Amazon region has been called the "lungs of planet Earth"; however, the region is occupied by urban areas where urban residents far exceed the rural population. As a consequence, since 1980, the region has also been defined as an "urban jungle" (Costa & Brondízio, 2011). Barbieri et al. (2007) highlight how the urbanization process in the Amazon region has been associated with rural–urban mobility linked to the building of roads for extractive activities.

Oil extraction is not the only cause of the Amazon region's urbanization; indeed, agriculture and deforestation increase the environmental pressure on these territories (Defries et al., 2010; Soares-Filho et al., 2006). However, the expansion of the oil frontier accompanied by road infrastructures is the main driver of the process. Different studies in the literature highlight that the chaotic and unplanned development of urban areas occurring in this peripherical area, together with oil exploitation and land use changes, can undermine the quality of life of citizens and rural inhabitants; this can be seen as an underdevelopment or lack of basic services, few diversifications of economic activities, and high rates of unemployment. Moreover, urban and demographic growth and land use change exert pressures on biodiversity and the ecosystems, eroding the natural capital used for indigenous people's well-being (Cabrera-Barona et al., 2020; Ryder & Brown, 2000; Kleemann et al., 2022). EAR is an important example of this territorial dynamic: at the beginning of 1970, oil exploitation started, and later, it triggered urbanization growth in previously remote areas mostly covered by forests and occupied by indigenous groups (Wilson & Bayón, 2015).

1.3. Ecuador, its Amazon oil development, and urban expansion

The study area is EAR, focusing specifically on those areas overlapped by oil blocks (Fig. 1): the concessions granted by the government to oil companies for exploration and exploitation activities. EAR occupies more than 40% of Ecuador (Fig. 1(a) and (b)), a small South American country crossed by the Ecuadorian line, with a total extension of 283,560 km^2 and 17.89 million inhabitants (Codato et al., 2023). Ecuador is considered a developing country with an economy based on primary product exportation, mainly crude oil and agricultural goods, such as bananas, coffee, cacao, flowers, and shrimp (Codato et al., 2023).

The tropical ecosystems of EAR, which are part of the high-biodiversity wilderness area of the western Amazon, and the presence of numerous indigenous nations with their traditional knowledge, contribute to making Ecuador one of the most important and well-known bio-cultural hotspots in the world. Much like the rest of the Amazon, EAR and its high biological and cultural diversity has faced—and is still facing—several direct and indirect pressures and threats, such as oil and mine exploitation, linear infrastructure projects, agriculture expansion and deforestation and urban sprawl, among others (Bass et al., 2010; Codato et al., 2023; Finer et al., 2008). Several natural protected areas were created in the effort to safeguard and conserve the remaining wilderness ecosystems, with different degrees of success; here, the most famous is Yasuni National Park (Fig. 1(a)) on the border with Peru (Bass et al., 2010). Moreover, since 1990s, indigenous groups have obtained ownership of vast areas—even if not all ancestral territories are legally recognized yet—and an intangible zone for protecting the Tagaeri-Taromenane (hereafter ZITT), an ethnic population in voluntary isolation (PVI), was created by the national government in 1999 (Fig. 1(a)) (Codato et al., 2023; Pappalardo et al., 2013; Salinas Castro et al., 2020).

EAR is organized in six provinces (Fig. 1(a)); in particular, in the two provinces of the north (Pastaza, Orellana), and, to a much lesser degree, Napo and Sucumbios, oil discoveries have made Ecuador an oil exporter since 1972; hence, its economy is heavily dependent on oil and the global market (Alarcón, 2022). Nowadays, oil blocks, both exploited and not yet exploited, cover about 60% of EAR, overlapping also with the province of Morona Santiago. Over the years, oil activities and their export have developed a series of complex economic, social, and environmental effects and issues at different geographical scales (Codato et al., 2023; Kimerling, 2006; Salinas Castro et al., 2020). Among others, the beginning of oil activities and the construction of the so-called "oil roads" have been indicated by different authors as the main driver of the urban expansion in EAR, at least in the early stages, together with the agrarian colonization promoted by the government, which has generated spontaneous displacement of settlers from other regions (Cabrera-Barona et al., 2020; González-Comín, 2023; Pichón & Marquette, 1996;

[1] Sacrifice zones are "extremely contaminated areas where vulnerable and marginalized groups bear a disproportionate burden of the health, human rights and environmental consequences of exposure to pollution and hazardous substances". This definition is reported in the Report of the Special Rapporteur on the issue of human rights obligations relating to the enjoyment of a safe, clean, healthy and sustainable environment of the Human Rights Council (UN).

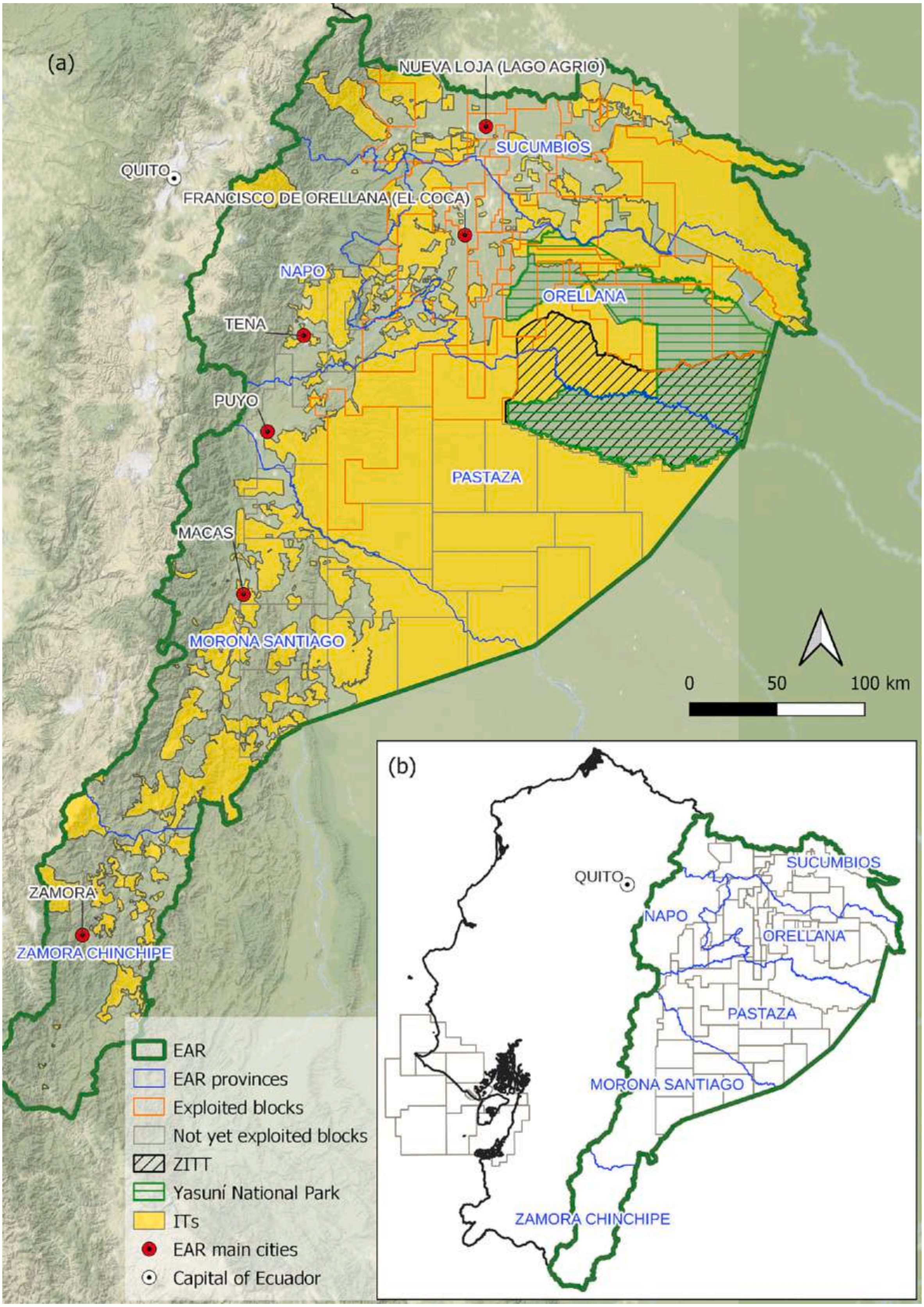

Fig. 1. Geographical framework of the study area. the map (a) presents EAR and its 6 provinces, the main cities, exploited and not exploited oil blocks, indigenous territories (ITs), Tagaeri Taromenane Intangible Zone (ZITT, Zona Intangible Tagaeri Taromenane) and the main protected area, i.e. Yasunì National Park, while the map (b) shows EAR within Ecuador.

Table 1
Main dataset used and their sources.

Sphere	Dataset	Description	Source
Oil	Oil production 1972–2012, other oil activity reports	Tables of annual oil production per oil field in thousands of barrels for the period 1972–2012, other info about oil production for the period 2012–2020	EP Petroecuador, 2017; MERNNR, 2021; AIHE, 2021
	Oil blocks	Spatial data of oil concessions as polygons	MERNNR, 2020
	Oil fields	Spatial data of oil fields as polygons	MERNNR, 2020
Urban	Urban infrastructure	Collection 4.0 of Amazon annual land use land cover for the period 1985–2020	RAISG, 2022
	IGM aerial photo	Oil exploration Texaco project, 1965	IGM, 2022
Socio-environmental	Indigenous territories	Spatial data updated at 2020 as polygons	RAISG, 2022
	Fatal accidents with PVI	Spatial data of fatal accidents related to clashes with PVI, as points	Amazon Frontlines (2017)
	ZITT and buffer zone	Spatial data of ZITT and its buffer zone as polygons	MAATE, 2022
	Social development index	Social index from literature	Larrea, 2017
	Oil spills and oil pits	Spatial data of recorded oil spills and pits as points updated until about 2022	MAATE, 2022
	Oil wells, pipelines, seismic lines	Spatial data of oil wells, pipelines and seismic lines updated until about 2020	MERNNR, 2020
	Gas flaring sites	Spatial data of gas flaring sites as points at 2018	Facchinelli et al., 2020

Salinas Castro et al., 2020; Ryder & Brown, 2000; Viteri-Salazar & Toledo, 2020). A variegate system of small and medium urban areas has been born, consolidated, and expanded as service settlements close to extractive (mainly for oil in the north and recently for mining in the south) and agricultural areas and more recently for tourism. Urbanization and the integration of EAR to the rest of the country began a century after the rest of Ecuador but in a very fast and chaotic way (Cabrera-Barona et al., 2020). As reported by González-Comín (2023), in 2010, about the 40–45% of the EAR population was living in consolidated and emerging urban areas with different degrees of infrastructures and services; these areas present the relative higher rate of growth of Ecuador (González-Comín, 2023). Hence, in a few decades, EAR has become a peripheral area of urban growth and resources extraction, one connected and integrated with the national and global economic systems, showing all the problems and challenges related to climate, social, and environmental justice issues that this process implies for the indigenous, for the population of settlers, and for the EAR ecosystems (Cabrera-Barona et al., 2020; González-Comín, 2023; Larrea, 2017).

1.4. Objectives

The general aim of the present study is to provide a first insight into the multiple injustice concept in fossil fuel extraction territories of the Global South into the climate justice perspective. Indeed, the current paper aims to show how these areas are at the same time urban peripheries of fossil fuel national benefits while also being entangled with the socio-environmental impacts caused and increased by oil activities, deepening the conditions of sacrifice zones[1].

This ambitious goal is pursued by the development of the following specific aims:

- Map and analyze the development of oil activities since its beginning in 1972.
- Map and analyze the spread of urban infrastructure since the first available Landsat satellite images in 1985, looking back to 1965 focus on Francisco de Orellana (El Coca) city.
- Analyze the spatial relationships between oil activities and urban infrastructure over the past 50 years.
- Investigate the spatial relationships between oil activities, urban infrastructure, and socio-environmental aspects, such as indigenous territories and recorded oil impacts.

2. Materials and methods

2.1. Dataset

Extensive research on open spatial and statistical data and scientific and gray literature has been carried out to reach the aims of the present study. Data can be grouped into three spheres (Table 1). The first is the oil sphere: different reports concerning oil activities, in particular tables of annual oil production statistics disaggregated at oil field (geographical area with oil reserves where oil exploitation is carried out) or oil block level for the period 1972–2012, the information of which is provided in the report "Informe Estadistico 45 años (Statistical Report 45 years)" produced by the public oil enterprise EP Petroecuador (2017) in pdf format; spatial data of oil blocks and oil fields provided by the Ecuadorian Ministry of Energy and Non-Renewable Natural Resources (MERNNR, Ministerio de Energía y Recursos Naturales no Renovables). For all analyses, we used the last available oil fields and oil blocks geometries, even if they changed a little over time, because of the lack of historical spatial data and to maintain the same spatial dimension. The second is the urban sphere: collection 4.0 of annual land use and land cover maps for the period 1985–2020 for the whole Amazon, which has been produced by the Amazon Network of Georeferenced Socio-Environmental Information (RAISG, Red Amazónica de Información Socioambiental Georreferenciada) in its MapBiomas Amazonia project (RAISG, 2021a). These maps are based on Landsat images classified using a workflow based on random forest classification in the Google Earth Engine (GEE) environment. Collection 4.0 comprises the class "urban infrastructure," which is defined as "area of human settlement associated with large and small urban centers (towns) with built environment infrastructure such as road networks, railways, and associated land, as well as other artificial areas such as hydrocarbon exploitation, hydroelectric plants, military bases, airports, port areas and unconventional airstrips in rural areas. It also considered peripheral areas that are being included in a gradual urbanization process toward residential purposes and/or industrial zones" (RAISG, 2021b). We downloaded the raster dataset for Ecuadorian Amazon for the year 1985 and then for every five years until 2020, using the GEE app available on the MapBiomas webpage. Moreover, we obtained an aerial image of the area around Puerto Francisco de Orellana City, taken in 1965 for the oil exploration Texaco project from the Ecuadorian Geographical Military Institute (IGM, Instituto Geografico Militar). The third is the socio-environmental sphere: spatial data of recorded oil impacts in the form of oil spills and oil pits sites were downloaded from the Ecuadorian Ministry of the Environment, Water, and Ecological Transition (MAATE, Ministerio del Ambiente, Agua y Transición Ecológica) Web Feature Service; seismic lines were obtained from MERNNR and gas flaring sites from the work of Facchinelli et al. (2020). Spatial data of ITs was downloaded from the Amazoniasocioambiental website, another project led by the RAISG network, while spatial data of ZITT and its buffer zone were provided by MAATE. Lastly, spatial data of fatal accidents with PVI, as approximate locations, was digitized using as reference the map showed in the webpage of Amazon Frontlines (2017).

Table 2
Sum of oil production per oil block since its beginning in 1972 and until 1985, 1990, 1995, 2000, 2005, 2010, and 2012, in thousands of barrels and in percentage respect to the total, according to the EP Petroecuador (2017) report for the period 1972–2012. Colors represent the starting period of production, from the dark red that corresponds to the more productive blocks that started before 1985, followed by light red since 1990, orange since 1995, dark yellow since 2000 and to the light yellow that corresponds to those blocks that started to be productive since 2005.

Block	1972-1985	1972-1990	1972-1995	1972-2000	1972-2005	1972-2010	1972-2012	1985%	1990%	1995%	2000%	2005%	2010%	2012%
B049	1,188	9,842	18,810	26,754	39,910	50,586	53,342	0.12	0.65	0.88	0.95	1.09	1.10	1.07
B050	340	835	1,280	1,674	1,679	1,679	1,679	0.03	0.06	0.06	0.06	0.05	0.04	0.03
B056	104,469	118,664	132,435	142,166	152,262	159,274	161,777	10.24	7.89	6.21	5.02	4.16	3.46	3.23
B057	516,807	783,708	1,078,132	1,322,823	1,507,599	1,643,273	1,700,645	50.67	52.10	50.56	46.75	41.22	35.75	34.00
B058	4,557	18,702	40,751	70,069	102,202	138,238	154,784	0.45	1.24	1.91	2.48	2.79	3.01	3.09
B060	302,862	408,504	521,442	612,947	689,388	795,977	874,355	29.69	27.16	24.45	21.66	18.85	17.32	17.48
B061	78,707	141,280	225,164	301,426	373,759	439,108	474,287	7.72	9.39	10.56	10.65	10.22	9.55	9.48
B062	10,578	20,150	28,756	70,087	155,510	233,250	259,074	1.04	1.34	1.35	2.48	4.25	5.07	5.18
B064	480	943	3,435	5,486	11,180	15,419	19,487	0.05	0.06	0.16	0.19	0.31	0.34	0.39
B044	0	837	7,965	14,014	17,548	21,051	22,671	0.00	0.06	0.37	0.50	0.48	0.46	0.45
B051	0	16	61	61	61	61	61	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B066	0	807	3,240	5,670	15,097	23,842	26,706	0.00	0.05	0.15	0.20	0.41	0.52	0.53
B007	0	0	18,537	48,874	72,076	99,389	112,828	0.00	0.00	0.87	1.73	1.97	2.16	2.26
B014	0	0	2,297	8,579	14,678	24,464	30,275	0.00	0.00	0.11	0.30	0.40	0.53	0.61
B015	0	0	26,032	72,833	124,561	269,292	298,868	0.00	0.00	1.22	2.57	3.41	5.86	5.98
B016	0	0	10,226	83,270	152,568	239,343	268,036	0.00	0.00	0.48	2.94	4.17	5.21	5.36
B045	0	0	320	320	320	718	1,752	0.00	0.00	0.02	0.01	0.01	0.02	0.04
B047	0	0	5,028	10,328	18,601	24,924	32,163	0.00	0.00	0.24	0.36	0.51	0.54	0.64
B052	0	0	56	121	121	121	121	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B053	0	0	403	479	479	479	479	0.00	0.00	0.02	0.02	0.01	0.01	0.01
B065	0	0	2,591	5,734	12,220	21,206	22,562	0.00	0.00	0.12	0.20	0.33	0.46	0.45
B067	0	0	5,444	10,497	13,428	24,204	28,303	0.00	0.00	0.26	0.37	0.37	0.53	0.57
B010	0	0	0	12,757	70,114	111,316	122,974	0.00	0.00	0.00	0.45	1.92	2.42	2.46
B011	0	0	0	84	250	252	252	0.00	0.00	0.00	0.00	0.01	0.01	0.01
B017	0	0	0	548	6,028	22,708	26,582	0.00	0.00	0.00	0.02	0.16	0.49	0.53
B018	0	0	0	15	20,336	73,808	86,592	0.00	0.00	0.00	0.00	0.56	1.61	1.73
B046	0	0	0	1,547	11,174	33,891	36,304	0.00	0.00	0.00	0.05	0.31	0.74	0.73
B055	0	0	0	256	256	256	256	0.00	0.00	0.00	0.01	0.01	0.01	0.01
B059	0	0	0	268	1,160	2,192	2,540	0.00	0.00	0.00	0.01	0.03	0.05	0.05
B012	0	0	0	0	63,818	94,618	136,874	0.00	0.00	0.00	0.00	1.74	2.06	2.74
B021	0	0	0	0	8,863	31,775	45,214	0.00	0.00	0.00	0.00	0.24	0.69	0.90
Total	1,019,988	1,504,288	2,132,405	2,829,687	3,657,246	4,596,714	5,001,843	100	100	100	100	100	100	100

2.2. Methods

A workflow composed of different but complementary steps, using a quali-quantitative geographical approach, was implemented in GIS opensource QGIS, R software, and Microsoft Excel environments; these steps are grouped and briefly described in this section, as follows:

- Spatialization of the oil production dataset: pdf tables of annual oil production in thousands of barrels per oil field and oil company for the period 1972–2012 (EP Petroecuador, 2017) were converted into Excel tables, and each oil field name was associated with the current oil field name available in the spatial dataset of oil fields provided by MERNNR. In cases of no correspondence between the old and current name, we used other sources of information (other reports and news from the web) to complete the match. A tabular join and other types of geoprocessing were then carried out to create two spatial datasets: oil fields and oil blocks with annual oil production and the sum of oil production since 1972 and until 1985, 1990, 1995, 2000, 2005, 2010, and 2012. Moreover, other statistics concerning oil production and oil activities for the period 2012–2020 were obtained by other reports (MERNNR, 2021; AIHE, 2021), to calculate the oil production range from the year production started for each oil block until 2020.
- Extraction and quantification of urban elements for the total EAR surface (about 116,000 km^2): urban elements (value n. 24 in raster map) were extracted from the land use and land cover raster of MapBiomas and converted into vector data. Spatial datasets and tables were then created by calculating the overlapping area of urban elements for 1985 and every five years until 2020, here in km^2 and percentage, for different spatial units, such as oil blocks, indigenous territories (ITs), and the six EAR provinces and by dividing all EAR in a regular grid of hexagons of 1 km distance between the opposite sides (for a total of 135,830 hexagons, see Fig. A1 in annex). For the focus on Puerto Francisco de Orellana (El Coca), we georeferenced the IGM aerial image of 1965 using the Landsat image of 1985 as a reference for ground control points placement; then, we digitalized the area occupied by settlements. Due to the difficulty in the georeferencing process because of the lack of ground control points and high root square error obtained, we used this information for qualitative purposes as a pre-oil period reference.
- Mapping of ITs, ZITT, and PVI fatal accidents.
- Quantification and visualization of socio-environmental oil impacts: we calculated the density per oil block of recorded oil spills, oil pits, and gas flaring sites, and shown the spatial distribution of seismic lines.
- All the above-mentioned datasets were then combined and geo-processed to produce maps and descriptive statistics of the relationships between oil, urban, socio-cultural, and socio-environmental oil impacts elements, taking into account the different temporal ranges covered by each element.

3. Results and discussion

The results are grouped and discussed in four sections, following the specific aims of the present study: the first section presents the results concerning the oil production in EAR between 1972 and 2020; the second section deals with the urban infrastructure analysis in the selected years and their relationships with oil activities; and in the third

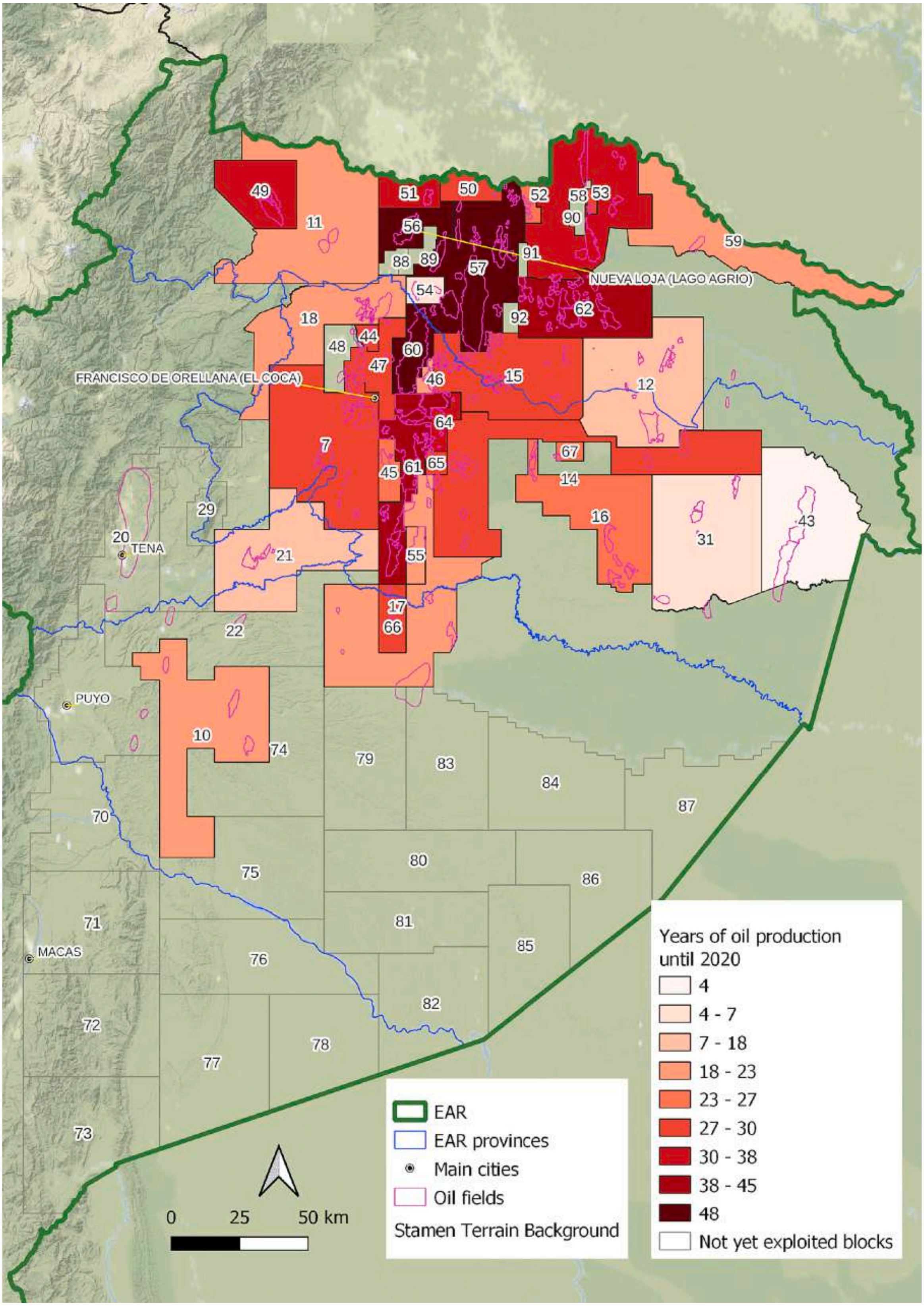

Fig. 2. Map of the oil production period of each exploited block until 2020, since the first blocks that started their production in 1972. A violet border highlights the oil fields, and a gray border highlights the blocks not exploited yet. The number in the blocks is their identity number. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

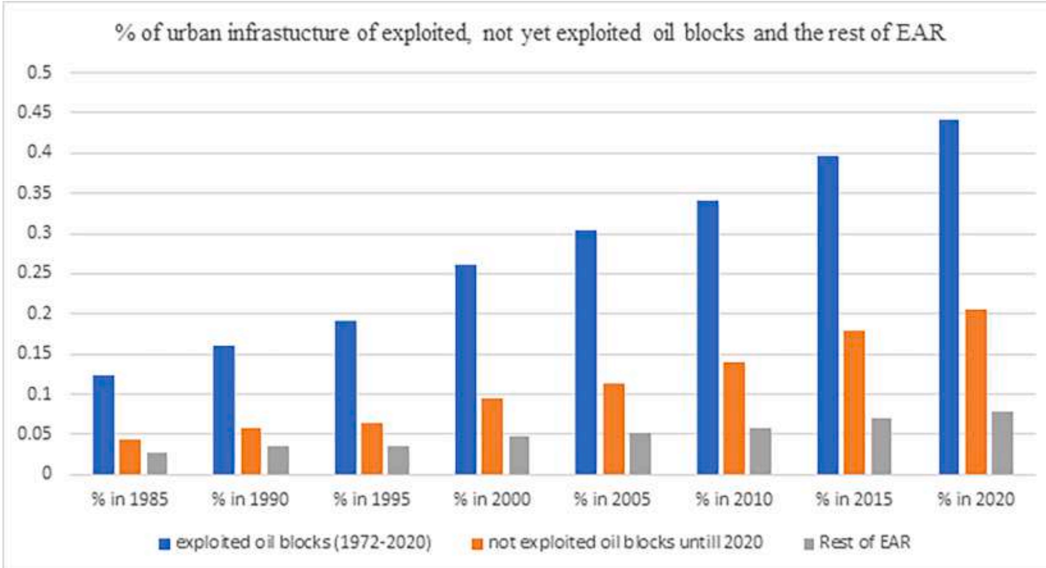

Fig. 3. Percentage of urban infrastructure overlapping the area of exploited oil blocks, of not yet exploited oil blocks (in 2020) and of the rest of EAR. The area of exploited blocks is 30,478 km^2 (26% of total EAR), not yet exploited blocks is 37,025 km^2 (32%), and the rest is 48,648 km^2 (42%).

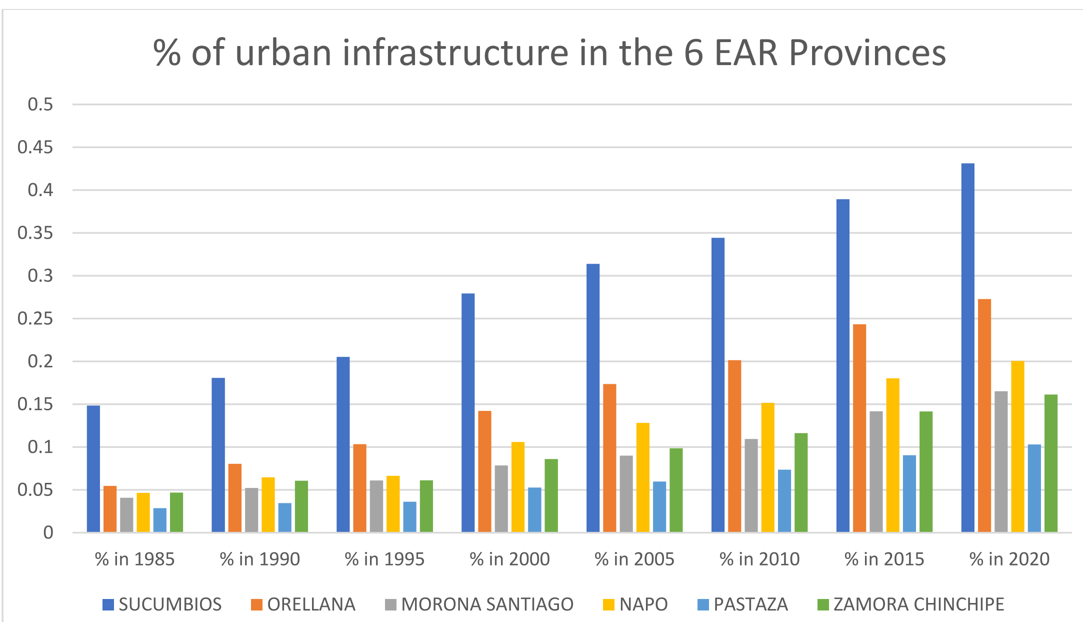

Fig. 4. Percentage of urban infrastructure of the six EAR provinces, where Sucumbios and Orellana are the two main "oil provinces". Sucumbios: 18050 km^2, 16% of total area; Orellana: 21548 km^2, 19%; Morona Santiago: 23981 km^2, 21%; Napo: 12513 km^2, 11%; Pastaza: 29495 km^2, 25%; Zamora Chinchipe: 10559 km^2, 9%.

section, we analyze the relationships between oil production, urban infrastructure, and socio-cultural and environmental aspects. Finally, the last section is dedicated to a discussion about climate justice in oil extraction territories, speculating about the multiple injustice concept.

3.1. Oil production in EAR

According to MERNNR (2021), the amount of oil produced since the beginning of oil exploitation in EAR in 1972 and until the end of 2020 was about 6.4 billion barrels, which can be divided into several oil fields comprised of 34 oil blocks. Between 96% and 99% of oil produced in Ecuador comes from this region, which can be seen by calculating the percentage of EAR oil production per year with respect to the total for Ecuador (MERNNR, 2021; EP Petroecuador, 2017). Table 2 presents the sum of annual oil production per oil block in thousands of barrels and in percentage respect to the total, since 1972 and for the year 1985 and every five years until 2010 and for the last recorded year (2012), as reported in EP Petroecuador (2017). We present the information until 2012 because this is the only report, as far as we know, that presents historical and consistent information about oil production disaggregated per oil field and oil company. Since the beginning and until 2012, a few blocks have consistently shown the highest production: the fields in blocks 57 and 60 keep being the most productive, as highlighted by their high percentage in Table 2, while block 56 decreased its importance over the years and left space for block 61 and the other three blocks (62, 15 and 16), which, in 2012, presented a cumulative production upwards of 5% of the total. The spatialization of this information and use of other reports to update the oil activity after 2012 (AIHE, 2021) is shown in

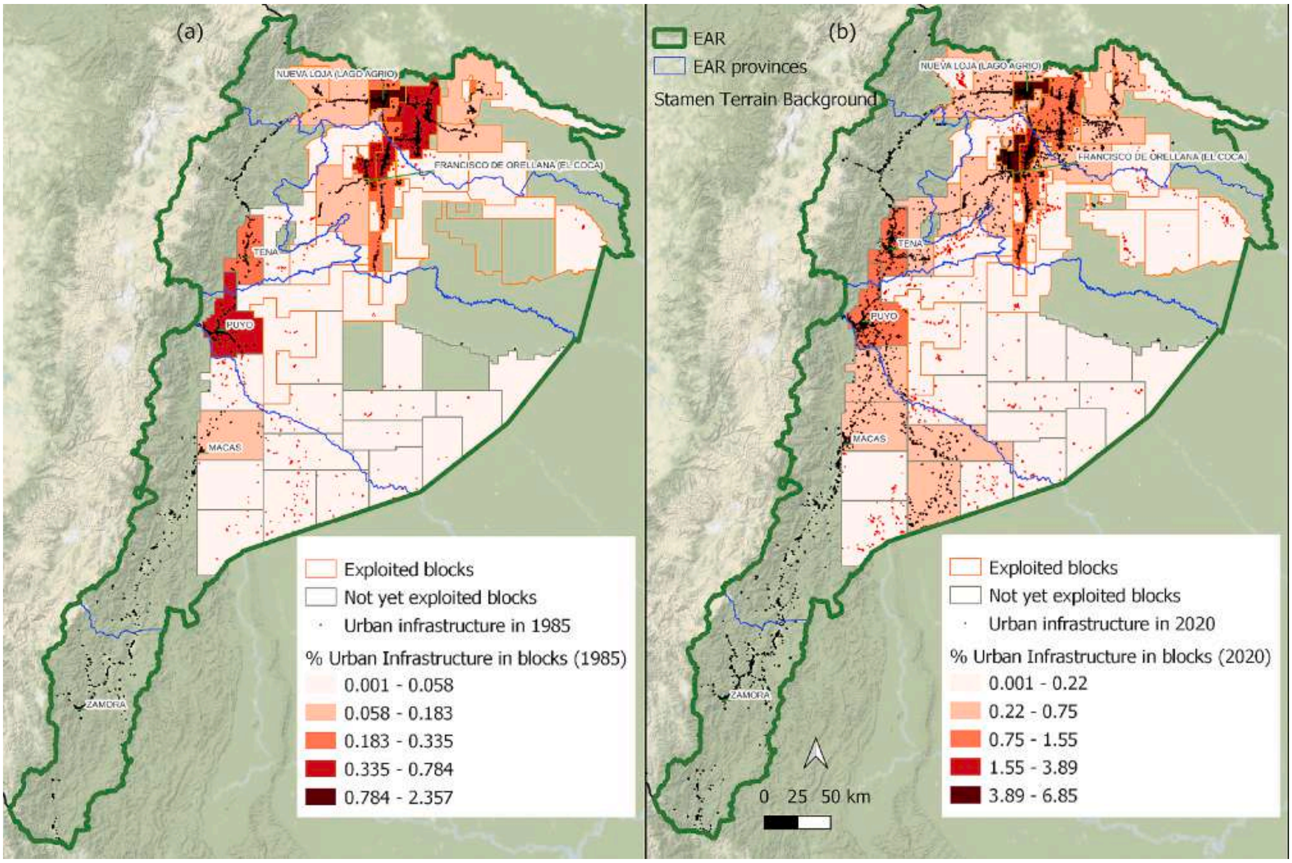

Fig. 5. Percentage of urban infrastructure of oil blocks in 1985 (a) and 2020 (b). Urban infrastructure for all EAR is emphasized using black dots instead of polygons to better visualize this item by increasing the size of the dots. Oil blocks are categorized as exploited (blue border) and not yet exploited (gray border), taking as a reference their status in 2020. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Fig. 2, which shows the spatial distribution of the oil production period since the starting year of each block and until 2020. In particular, the map highlights the starting of oil exploitation in the northern EAR (nine oil blocks colored in dark red in Table 2), where the first ones, dated 1972, are Lago Agrio (block 56), blocks 57 (Shushufindi-Libertador) and 60 (Sacha); in the subsequent years, the original blocks are followed by other northern oil blocks and block 61 along the Auca oil roads system. Other oil blocks started their production after 1985 and until 2005, mostly between 1990 and 2000; these blocks are speared in the northern and central part of EAR (different colors in Table 2 and map in Fig. 2). Map in Fig. 2 also shows the three oil blocks that started their production after 2012, that is, blocks ITT (43, since 2016) and Apaika-Nenke (31, since 2013), which surround Yasuni National Park and the ZITT, and block 54 since 2014.

3.2. Spatial relationships between urban infrastructure and oil production

Since the first available data for 1985 and until 2020, oil exploited EAR has continued to be the most urbanized part. We examine this situation by analyzing the percentage of urban infrastructure for the different years and by considering different spatial scales. The chart in Fig. 3 shows the percentage of urban infrastructure between 1985 and 2020 related to those areas under oil exploitation and areas not yet exploited in 2020, and the percentage of urban polygons overlapping EAR not interested by this activity. Here, the percentage of urban elements of exploited oil blocks area keeps being higher than in nonexploited oil blocks. Urban infrastructure represented 0.12% of exploited and 0.04% of nonexploited area in 1985, and there was continuous growth in both categories, with the exploited one reaching 0.45% in 2020 and 0.20% in the other block area. To extend the analysis to every part of EAR, we also analyzed the percentage of the six EAR provinces area overlapped by urban infrastructure (chart in Fig. 4) and divided EAR in a fishnet of regular hexagons (chart in Fig. A1 in the annex) to compare spatial units of the same size: the first chart highlights the higher percentage of urbanization of the two most exploited provinces, that is, Sucumbios and Orellana, where the former one, which hosts also the oldest blocks, presents very high values compared with the others. The charts in the figure in the annex (a2) represent the boxplots of the percentage of urban infrastructure of all the hexagons (excluding hexagons with a 0 value) in exploited and nonexploited areas while considering three reference years: 1985, 2000, and 2020. For each box plot, the mean and median statistics are higher for hexagons in exploited blocks compared with the rest of EAR (Table A2 in annex). This different presence of urbanized infrastructure could be explained by the initial opening of new roads and urbanization and building of infrastructures occurring for oil activities, which has been fostered by the colonization by oil workers and new settlers in search of new economic opportunities or agricultural lands, phenomena started later and for other dynamics (for example mining) in the not exploited areas, as reported in the literature (Cabrera-Barona et al., 2020).

Regarding the spatial dimension of urban elements in EAR and within its oil blocks, maps 5(a) and 5(b) in Fig. 5 present the percentage of each oil block area overlapped by urban infrastructure in the first and last of the analyzed years, that is, in 1985 and 2020, respectively. The black dots also give the spatial distribution of urban elements for all EAR. Oil blocks are categorized as exploited (orange border) and not yet exploited (gray border), taking as a reference their status in 2020. The same figure is included in the annex (a3) for better visualization. Since the beginning of oil exploitation, most urbanized blocks correspond to areas with the longest history of oil production or areas around and

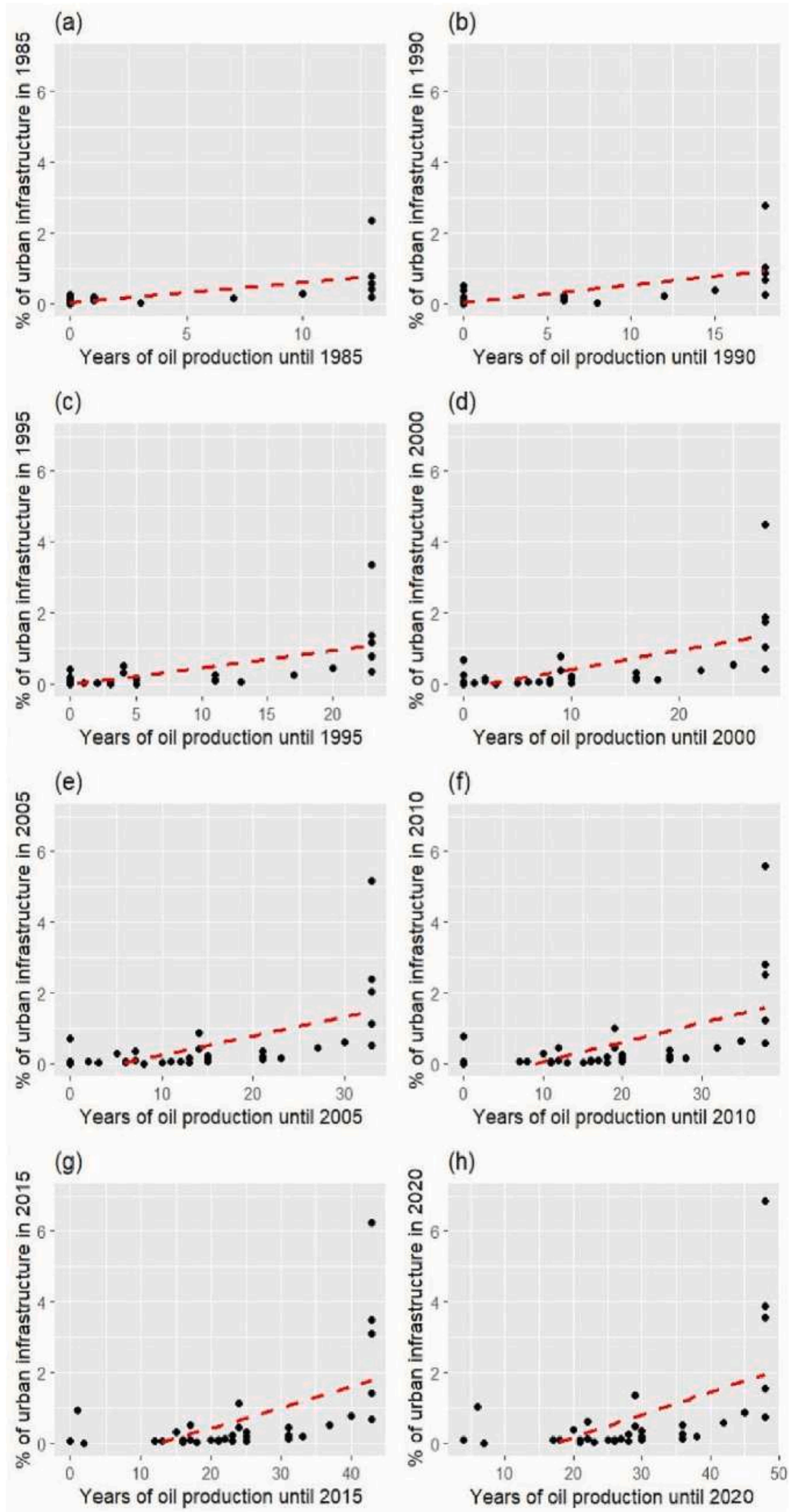

Fig. 6. Regression analysis of the percentage of urban infrastructure in the different years (dependent variable) related to the oil production period since 1972 and until the year indicated in each chart (independent variable). We consider only exploited blocks.

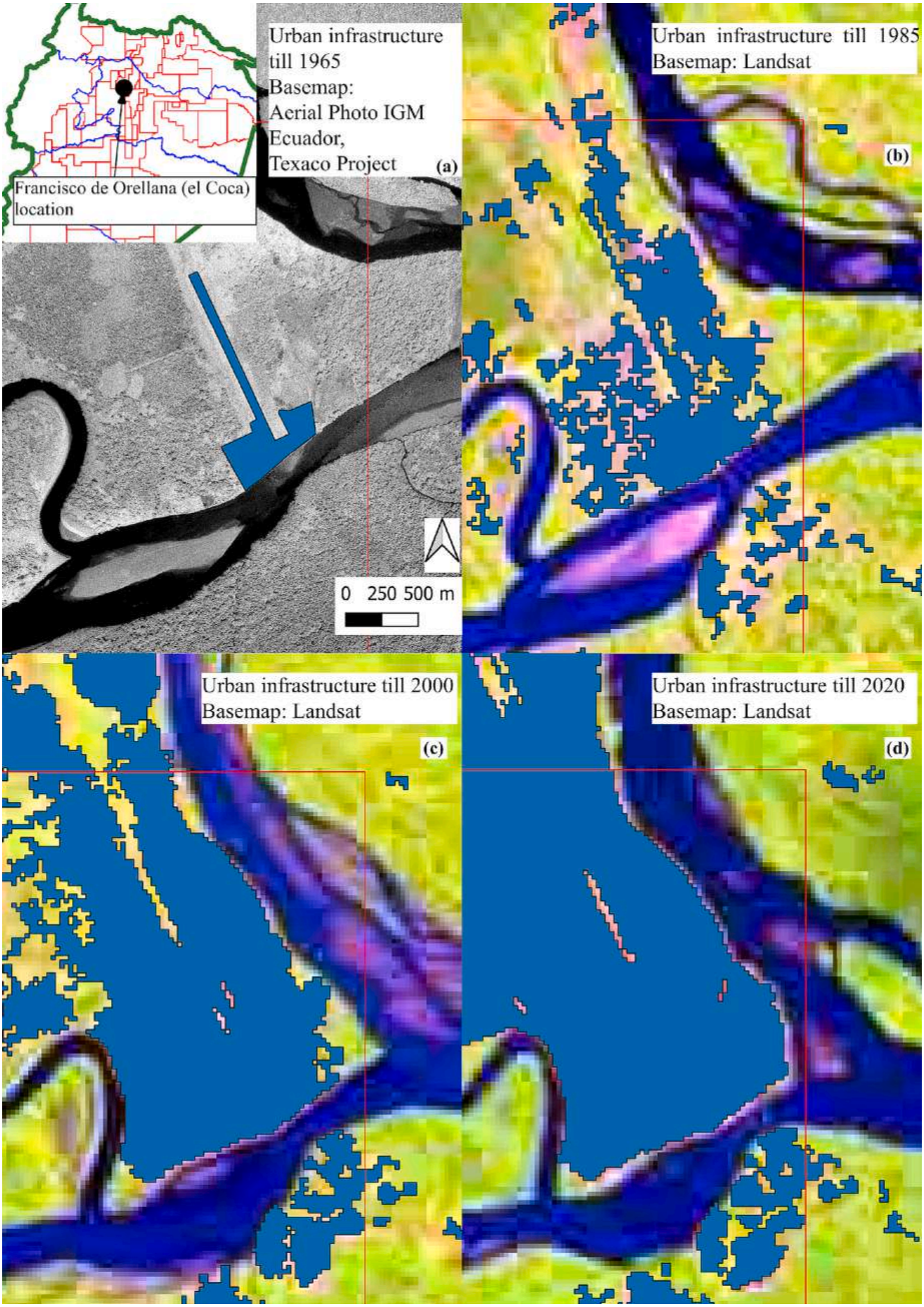

Fig. 7. Focus on Puerto Francisco de Orellana (El Coca) urban area development between 1965 (pre-oil expansion period) and 2020.

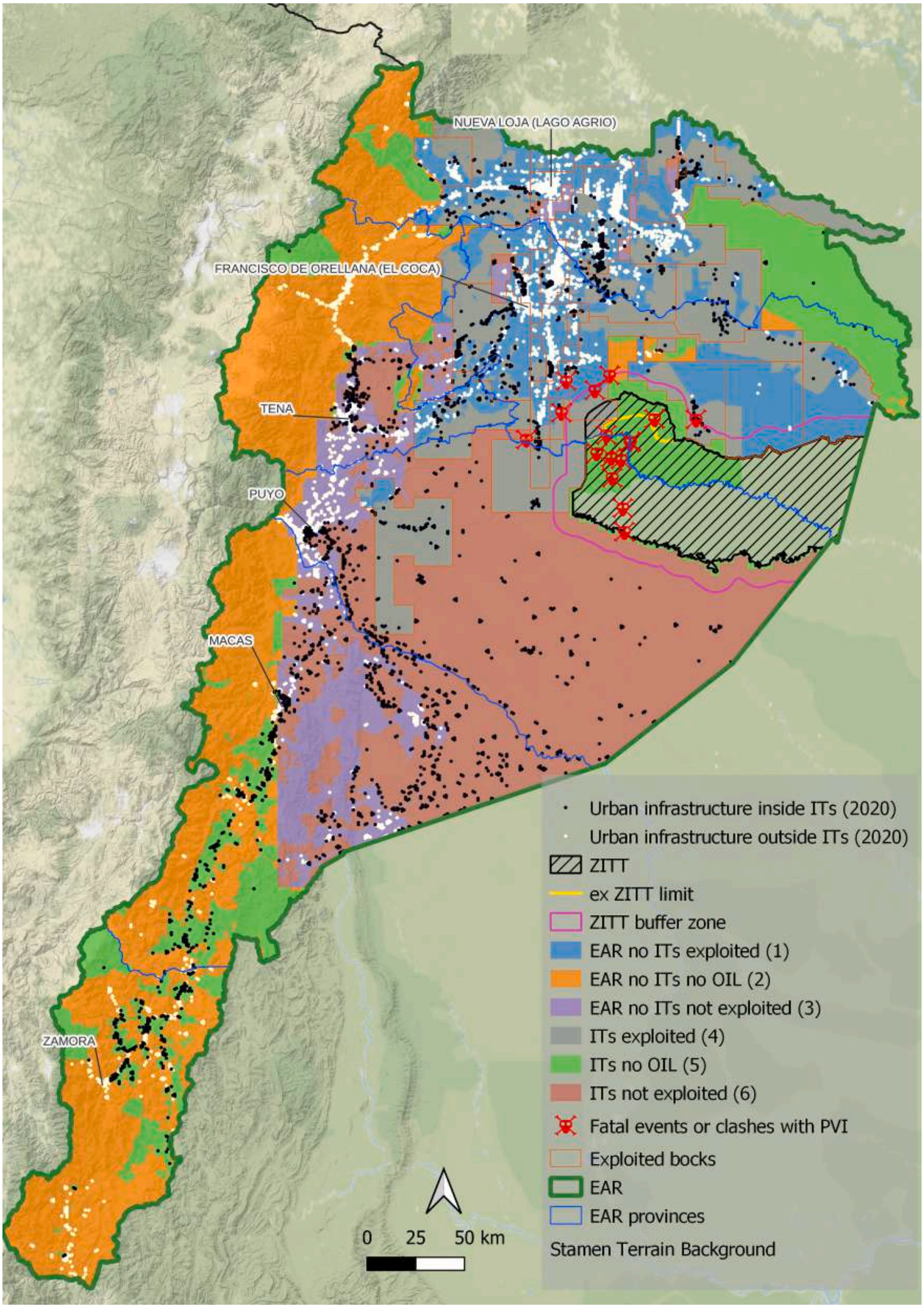

Fig. 8. Map of the spatial relationships between urban infrastructure (in 2020) inside and outside ITs and the whole EAR related to ITs and oil exploitation. ZITT and its historical deaths are highlighted. (1) EAR no ITs exploited (14,650 km^2, 13% of total area): area of exploited oil blocks outside ITs; (2) EAR no ITs no OIL (28,063 km^2, 25%): area of EAR not overlapped by oil blocks nor ITs; (3) EAR no ITs not exploited (8,195 km^2, 7%): area of EAR overlapped by not yet exploited oil blocks, without ITs; (4) ITs exploited (15,827 km^2, 14%): area of ITs overlapped by exploited oil blocks; (5) ITs no OIL (14,964 km^2, 14%): area of ITs outside oil blocks; (6) ITs not exploited (28,830 km^2, 26%): area of ITs overlapped by not yet exploited oil blocks.

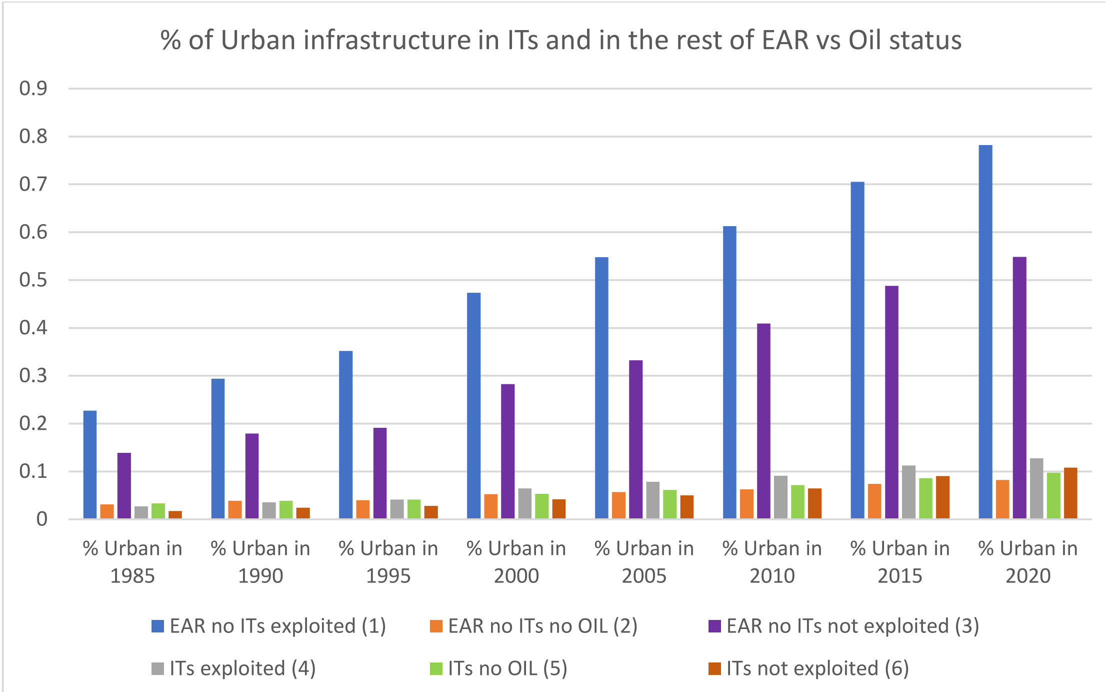

Fig. 9. Percentage of urban infrastructure inside and outside indigenous lands overlapped by exploited and not exploited blocks and in EAR overlapped or not overlapped by oil blocks. ZITT area is excluded and treated separately.

connected to the most productive blocks, in particular in Sucumbios and Orellana, which have seen the development of important small and middle urban centers, such as Puerto Francisco de Orellana (El Coca), which is between blocks 47 and 7, Nueva Loja in block 56, or Shushufindi in block 57. In particular, the block that hosts Nueva Loja presents the highest percentage for all years, reaching almost 7% of the urbanized area in 2020. Different smaller urbanized areas also grew along the principal oil roads and river networks, such as Dayuma, which is situated along the Auca road system in block 61 or Tiputini in block 43, where production started in 2016. An interesting exception is represented by block 10, a productive block in ITs but with a low percentage of urban elements, where oil exploitation at the end of 1990s was developed without opening any oil roads, and only recently, around 2010, a road system was implemented by the local government. Among the first 20 most urbanized blocks in 1985, 10 (four are at the top) were involved directly or indirectly in oil activities, while in 2020, this held true for 14 (with five at the top). Some exceptions are represented by nonproductive oil blocks, where there are important historical cities far from current exploited areas in the interface between the Andes and Amazon, such as Tena (block 20 in sixth place in 2020 and eighth in 1985), Puyo (block 28 in seventh place in 2020 and fifth in 1985), and Macas (block 71, in seventeenth place in 2020 and fifteenth in 1985), which, however, have never reached the urbanization of the exploited part.

The relationship between oil activities and urban infrastructure is also shown in the linear regression analysis presented in Fig. 6 (statistics in table in Annex A2). In this case, we focus only on the exploited blocks, and each graph (from a to h) presents the percentage of urban infrastructure area of each block (y axis) and the years of production (x axis) since the starting year of each block and until the year indicated. Each year shows a displacement of blocks (black dots) to the right because of the starting exploitation of new blocks and an increase in the percentage of urban elements. Visible is block 56 (Nueva Loja, with 13 years of activity in 1985 and 48 in 2020), which is located as a dot on the upper right corner of the box as a sort of outlier, because it has the highest percentage of urban infrastructure and has been productive since start. For all years, the linear regression analysis shows a positive correlation between years of activity and a higher percentage of urban infrastructure. It is worth mentioning that, in this analysis, blocks 47 and 7 are considered productive since 1972 because they comprise Francisco de Orellana (El Coca), a service city for oil production that started its development almost at the beginning of oil activities, even if these blocks became productive in the 1990s.

The maps in Fig. 7 focus on the urban evolution of Puerto Francisco de Orellana city, known also as El Coca, the capital of the Province of Orellana. This city (about 72,000 inhabitants) represents an example of urban territorial changes in a highly sensitive ecological and cultural remote area of EAR; the city growth has been strongly influenced by external economic interests and natural resources overexploitation. In fact, it is located close to the first and most exploited oil areas of EAR, assuming the role of the main service center, and it is the gate of the Auca oil road system that runs south mostly in block 61. For these reasons, its past territorial dynamics, as well as urban growth, are intimately related to fossil fuel production, even if the oil infrastructures are not located inside the city (González-Comín, 2023). The urban area in map in Fig. 7(a) is digitalized on a georeferenced aerial photo from 1965 provided by IGM Ecuador and taken for oil exploration purposes but before the massive oil exploitation projects. It shows a small area located near the river and occupied by a small airport and a few sparse buildings surrounded by some agricultural areas. Map 7(b) shows the situation in 1985, where urban areas started to grow also in the south side of the Napo River, thanks to the building of a bridge and new roads, and the other maps of 2000 (c) and 2020 (d) the consequent urban expansion.

3.3. *Socio-cultural and environmental aspects and their relationships with oil production and urban infrastructure*

We considered two aspects that could show the effects of oil exploitation and urban infrastructure on the socio-cultural and environmental sphere: 1) ITs and the welfare and well-being of the EAR inhabitants and 2) oil infrastructure and socio-environmental impacts.

The situation of ITs and their relationships with oil activities and

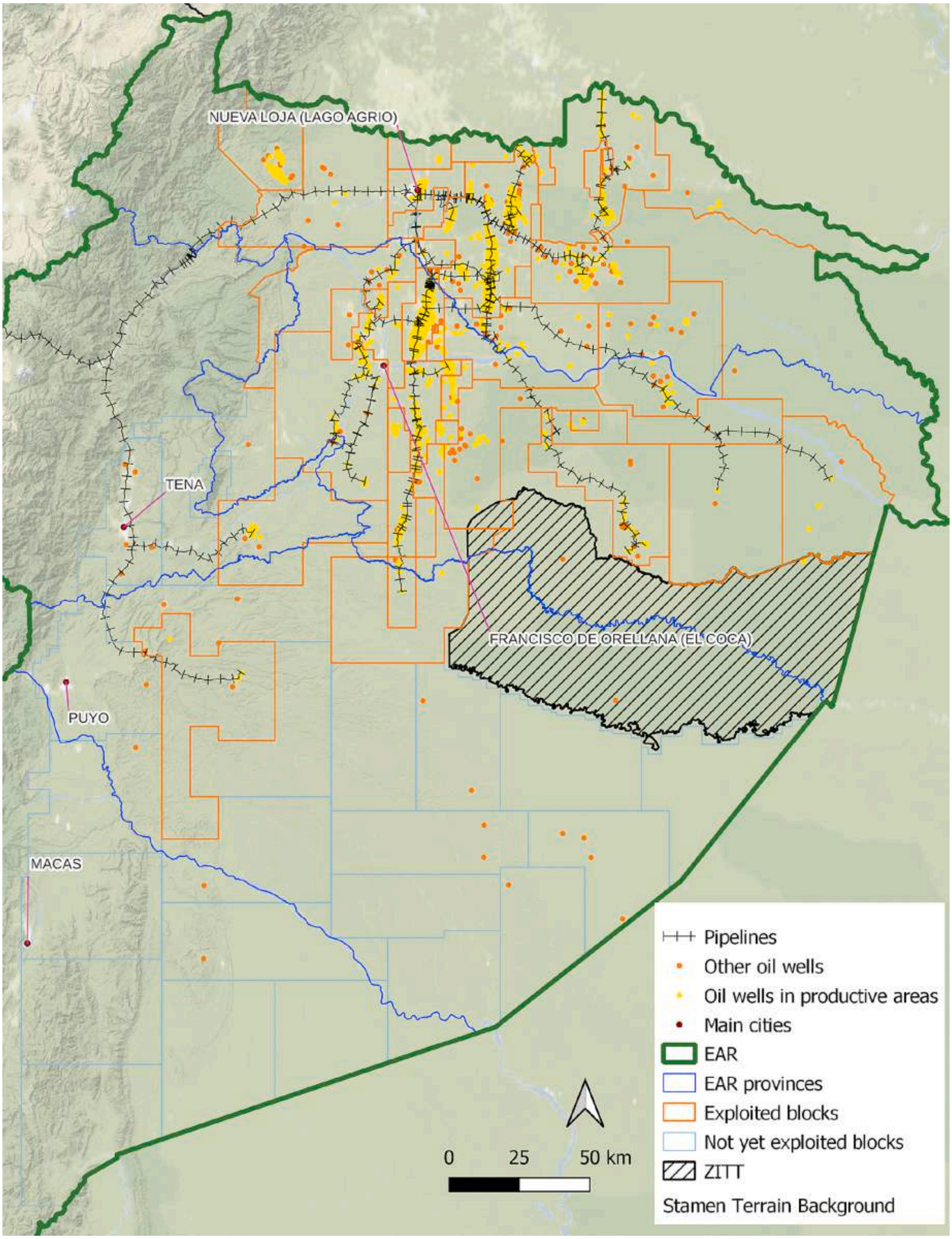

Fig. 10. Main oil infrastructures in EAR.

urban infrastructure is shown in the synthesis map for 2020 (Fig. 8) and related graph (Fig. 9) indicating the evolution of urban infrastructure in the different years. These figures show ITs and the rest of EAR categorized in different sectors according to their relationships with oil activities, that is, if they are overlapped by exploited blocks, by not yet exploited blocks, and territories without any oil block. We distinguish between areas overlapped by not yet exploited oil blocks and areas free of oil to appreciate the part of EAR and ITs that could be interested in this activity in the future. Moreover, urban infrastructure is shown in black dots when it is located in ITs and in white dots when in the rest of EAR outside ITs. Even if urban infrastructures are located mainly outside of ITs and in exploited or nonexploited blocks, there is an increasing of infrastructures, especially in ITs overlapped by exploited oil blocks, which, in the northern part, are surrounded and penetrated by urban elements of areas with oil activities. As recognized in social impact assessment literature, urban expansion related to resource exploitation,

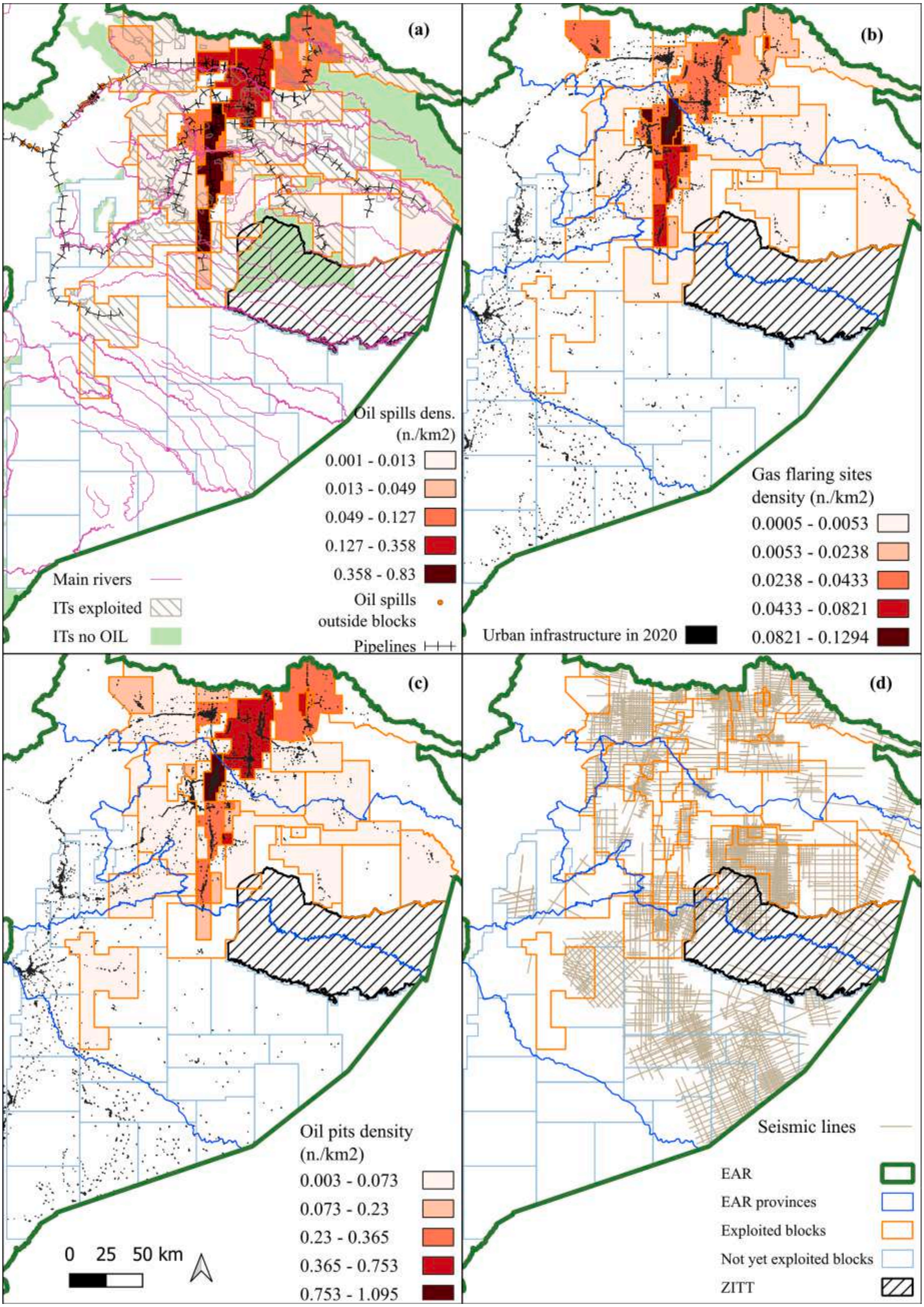

Fig. 11. Recorded oil impacts: (a) oil spills density per block, (b) gas flaring sites density per block, (c) oil pits density per block, (d) seismic lines.

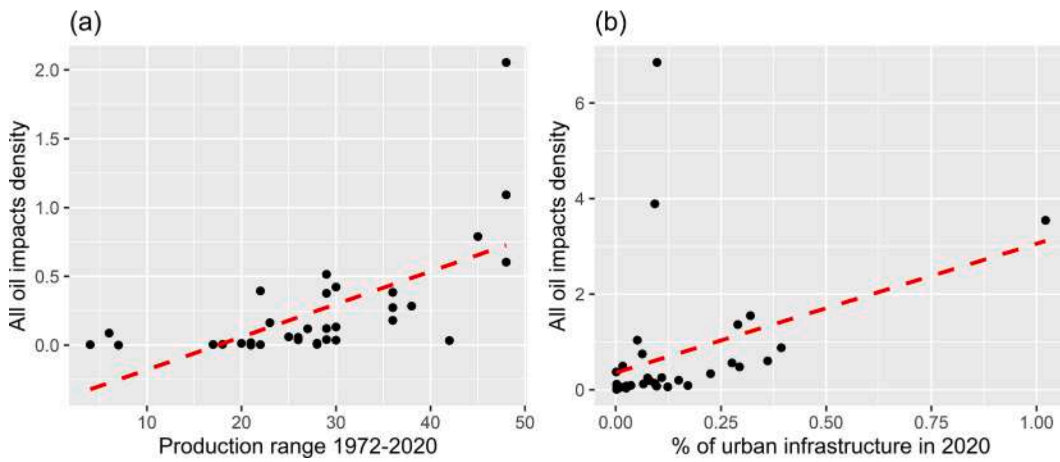

Fig. 12. Regression analysis of the relationships between oil impact density and oil production period for each exploited block (a) and regression analysis of the relationships between oil impact density and the percentage of urban infrastructure overlapping each exploited block in 2020 (b).

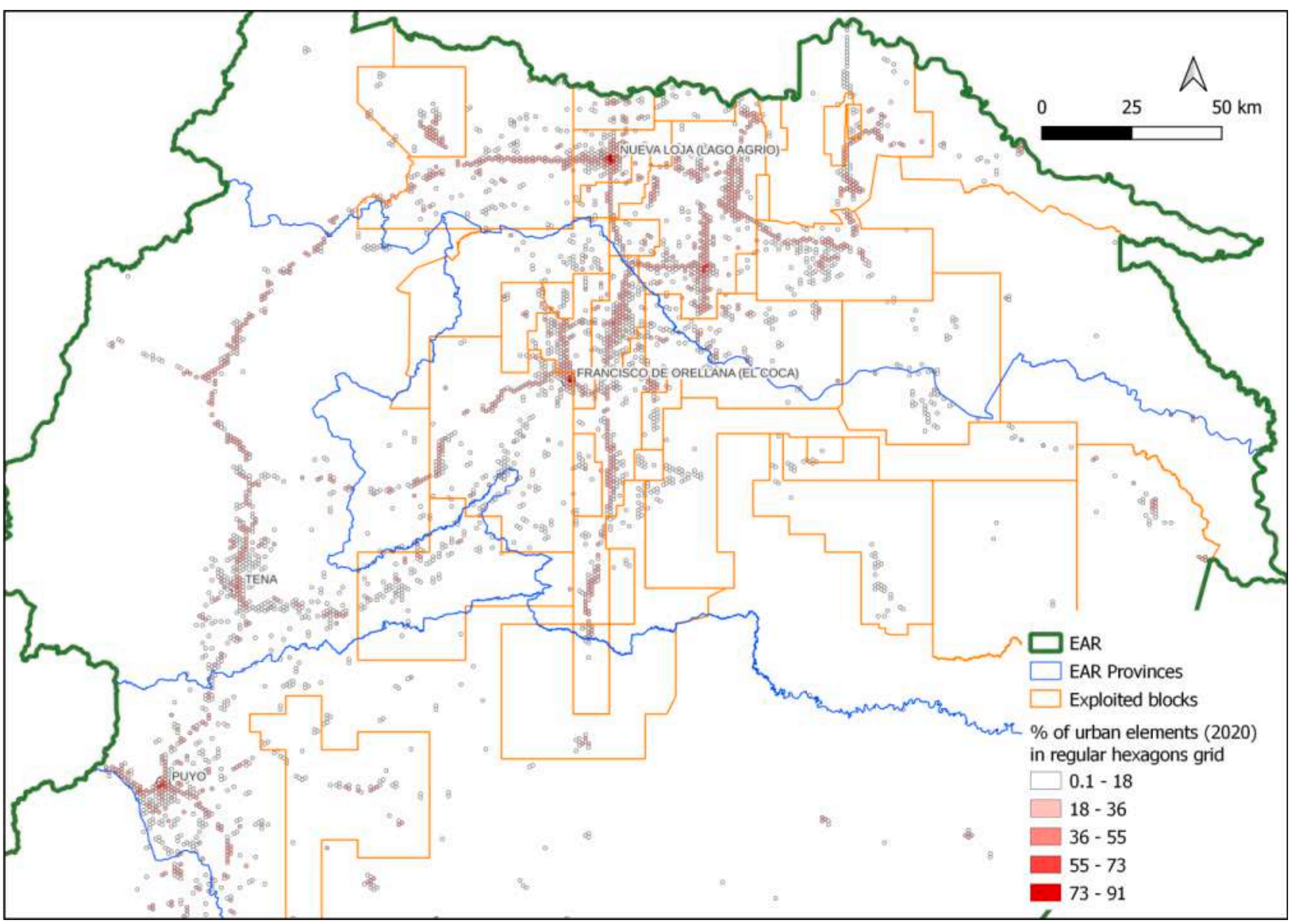

Fig. a1. An example of hexagonal grid used for urbanization analyses (see Fig. a2). Only hexagons with an overlap of urban infrastructure > 0 is showed.

produces several adverse effects on indigenous behavior and their traditional knowledge and practices, such as displacement, migration to urban areas and village abandonment, dependence to the global market, and an effect on their traditional relationships with the forest (Cabrera-Barona et al., 2020; Lyall, 2021; Salinas Castro et al., 2020; Viteri-Salazar & Toledo, 2020). In particular, at the early stage, the entrance of oil companies and other external actors implied a disproportionate level of power in the relationships with indigenous people in favor of these external actors, along with few or null involvements in the decision-making processes, in addition to growing dependency relationships, where oil companies often took the role of the government in offering essential services (Diantini et al., 2020; Kimerling, 2006). Over time and depending on different factors, power relationships between indigenous communities and oil companies (and the government) have transformed and evolved, leading to different forms of resistance and negotiations with different outcomes but which have seen a growth of the empowerment of indigenous peoples and their associations and a progressive reconquest of their ancestral territories (Diantini et al.,

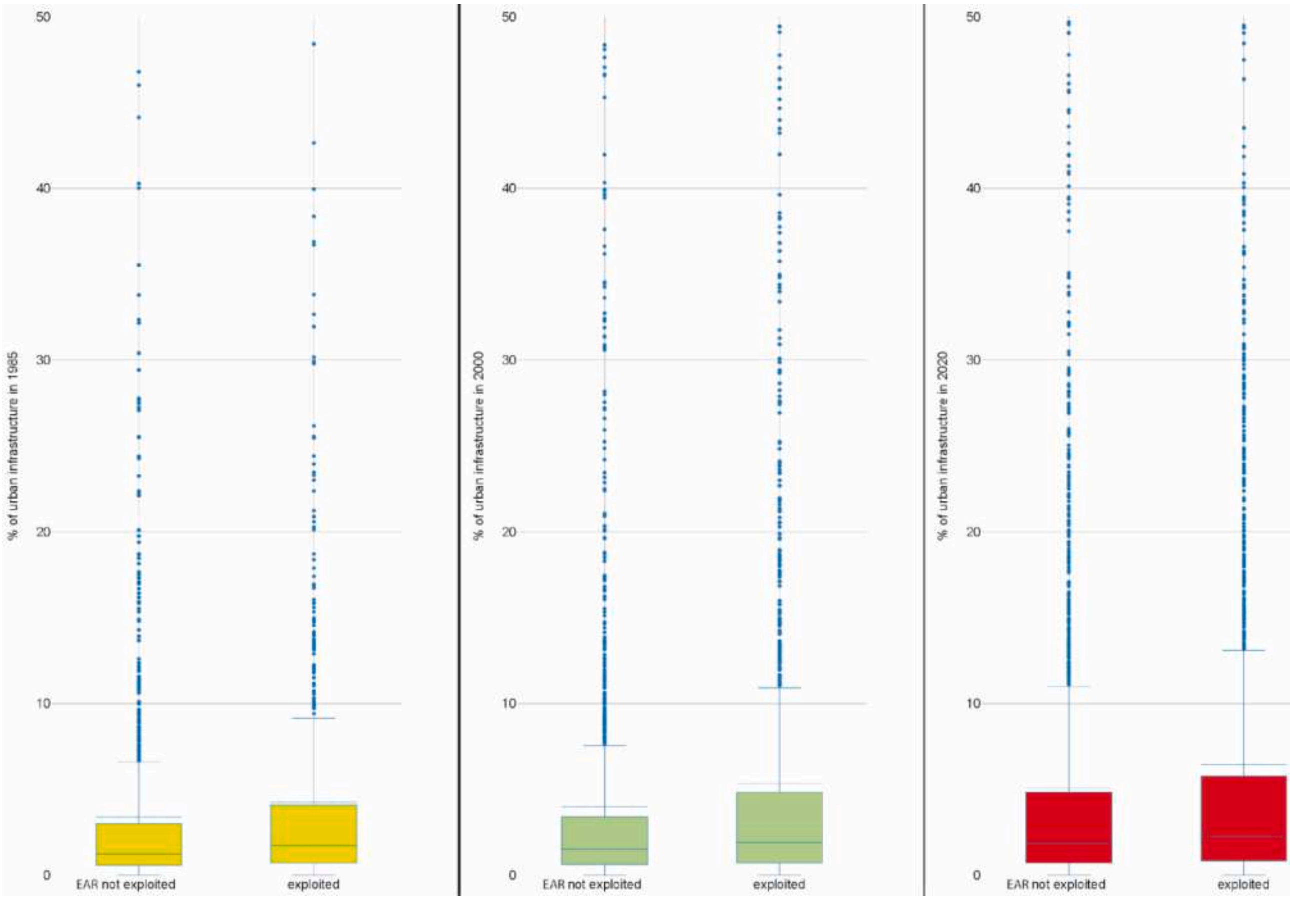

Fig. a2. Boxplot of the percentage of urban infrastructure in the hexagons in exploited oil blocks and in the rest of EAR in 1985, 2000 and 2020.

2020; Lyall, 2021; Salinas Castro et al., 2020).

Fig. 8 also shows the current ZITT area, that is, the area established in 1999 by the government for the protection of PVI Tagaeri-Taromenane indigenous group (Pappalardo et al., 2013), which was defined in 2007 and enlarged in 2018 in its northern part after a long process (Codato et al., 2023). ZITT and its buffer zone should be considered a "no-go" zone for any type of activity. As we can see in the map, this area has been surrounded by urban infrastructure and oil activities for many years in its north-west part and, more recently, also in the north-west in blocks 31 and 43 (see also map in Fig. 5, where we can appreciate the increase of urban dots in these two blocks from 1985 to 2020). Even if a long history of struggles and demands by organizations of civil society have allowed an increase in the protection of this area, pressures are still threatening this population (Opendemocracy, 2022). Red skulls represent approximative places of fatal events or clashes occurring between 1970 and 2013, usually with oil workers, illegal loggers, and other indigenous people, mostly close to anthropic activities; different cases occurred also in oil and urbanized areas, showing that also the current ZITT and its buffer zone is not sufficient to protect this population.

Regarding the welfare and well-being of the population living in EAR, in the work of Larrea (2017), the Social Development Index, which is composed of several indicators and based on the last three national censuses (1990, 2001, and 2010) is used to investigate this aspect in relationships with oil activities. Even if the authors indicate that a more in-depth analysis is needed to state the correlation, as shown in Table A3 in the annex, both urban and rural oil EAR present lower social development values for all the three periods with respect to its nonexploited counterpart. The authors indicate the low connection of oil activity with the local economy and poor capacity of local governments to redistribute oil revenues as the main factors behind this situation (Larrea, 2017). Pontarollo et al. (2020) report a general negative effect of oil exploitation on subjective well-being. Moreover, literature reports that inhabitants face several negative consequences related to climate change, such as an increase of temperature and frequency of drought (Salinas Castro et al., 2020; Viteri-Salazar & Toledo, 2020), which could affect both the lives of citizens and rural areas.

Finally, to visualize what oil exploitation leaves in EAR, the final maps and analysis present the main oil infrastructure (Fig. 10) and recorded oil impacts (Fig. 11) of the exploration and exploitation phases, along with their relationships (Fig. 12). Fig. 11 shows the density of recorded oil spills (a), gas flaring sites (b), and oil pits (c) per block, while Fig. 11(d) shows the seismic lines opened for oil exploration. For oil spills (Fig. 11(a)), we also show the dots of what has been recorded outside blocks, usually associated with the pipeline, the main river network that flows from west to east (toward Peru and Brazil), and the ITs categorized as in exploited blocks or free of oil activities, to emphasize that oil spills in this high precipitation area could carry the pollution very far and contaminate soils and the water resources of many people, also at a cross-border level, which has occurred in the past (Alvarado, 2022). For the almost 1,400 oil spills and more than 3,000 oil pits recorded by MAATE, only 25% and 43%, respectively, are categorized as remediated, while the rest are classified as in process. Most impacts of exploitation occurred in urban and rural areas inside or close to elder and most exploited blocks: besides the maps of Fig. 11, this is shown by the regression analysis in Fig. 12: the first graph (a) regards the relationships between the years of oil production until 2020 and oil impact density per exploited block, while the second graph (b) analyses the relationships between oil impacts density and the percentage of urban elements in 2020. As a consequence, both of them show a positive correlation (statistics are presented in Table A4 in the annex). Fig. 11(d) presents the distribution of seismic lines as a proxy of the possible impacts in the exploration phase that can last for a longer period of time

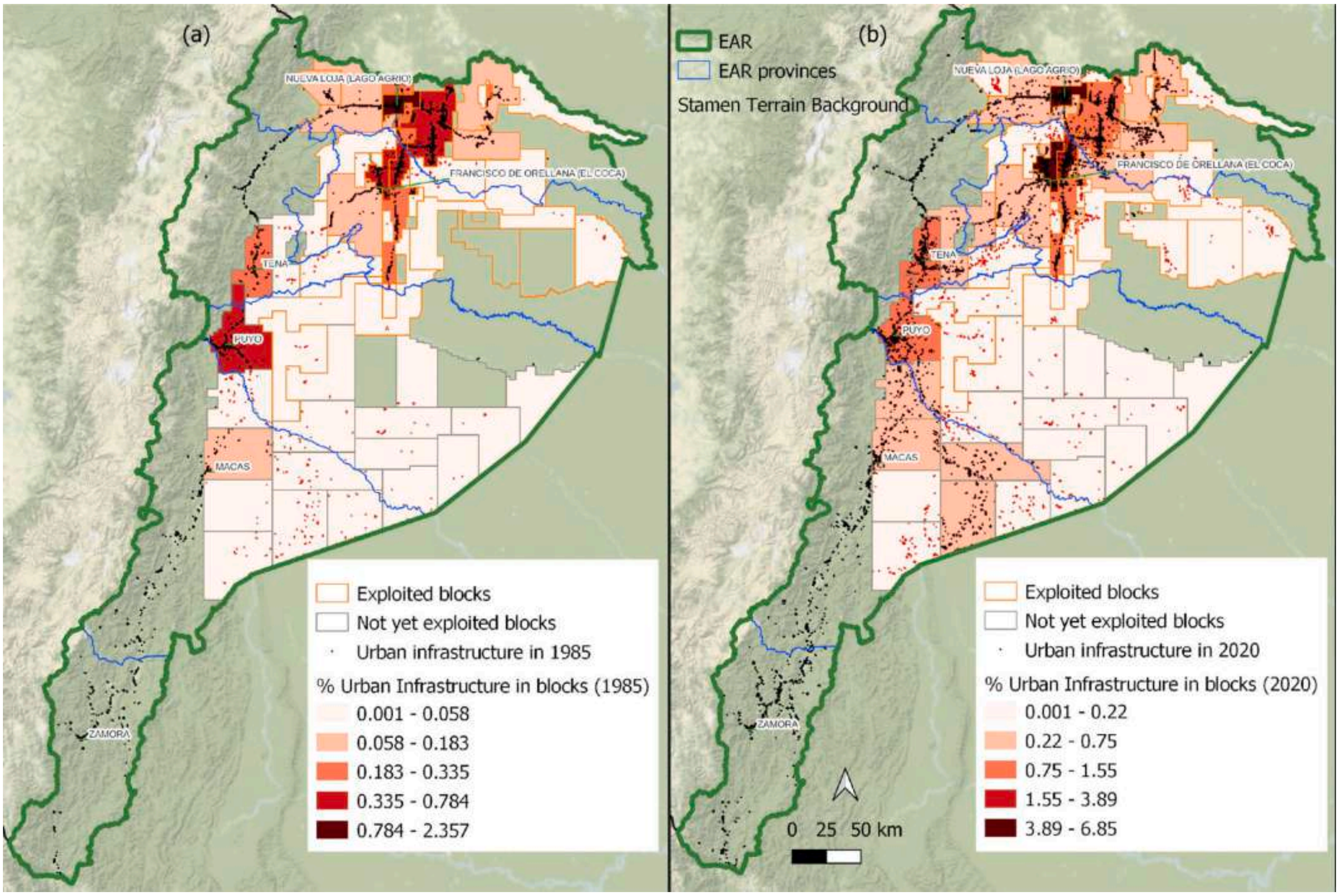

Fig. a3. Percentage of urban infrastructure per oil block in 1985 (a) and 2020 (b). Urban infrastructure for all EAR is emphasized using black dots instead of polygons to better visualize this item by increasing the size of the dots. Oil blocks are categorized as exploited (blue border) and not yet exploited (gray border), taking as a reference their status in 2020.

Table A1
Mean and median values of boxplots of Fig. A2.

	1985 mean	1985 median	2000 mean	2000 median	2020 mean	2020 median
Exploited area	4.24	1.74	5.33	1.90	6.46	2.27
EAR not exploited	3.39	1.24	3.97	1.52	5.07	1.86

Table A2
Regression analysis statistics between years of oil production and percentage of urban infrastructure

	1985	1990	1995	2000	2005	2010	2015	2020
Intercept	0.03172	0.034789	−0.01777	−0.1133	−0.30499	−0.50129	−0.74009	−1.12139
β Coefficient	0.05716	0.04962	0.047245	0.05213	0.05435	0.05501	0.05811	0.06402
β p-value	2.65E−05	1.96E−05	3.72E−05	0.000131	0.000273	0.000454	0.000707	0.00073
R^2	0.4288	0.439	0.417	0.3713	0.3431	0.323	0.3051	0.3037
Residual Std. Err.	0.3254	0.3916	0.4866	0.684	0.8132	0.9181	1.07	1.188
correlation	0.65	0.66	0.65	0.61	0.59	0.57	0.55	0.55

because of their potential effect on forest fragmentation (Dabros et al., 2018). This activity interested almost all northern and central EAR and was also carried out in the ZITT area. Although the benefits from oil production in the exploited areas appear to be very limited compared with the profits of oil companies, the revenues of the Ecuadorian government and benefits of other external actors, oil exploration, extraction, and transportation, carried out in highly sensitive areas negatively impact the health and well-being of local population, as recorded many times in the literature about toxic environment and sacrifice zones (Coronel Vargas et al., 2020;; Ramirez et al., 2017; Uyigue & Enujekwu, 2017; Finer et al., 2008; Randolph, 2021). In Fig. 10, we show oil wells in productive areas and other types of oil wells (closed, for exploration purposes, etc.) and pipelines to visualize where the possible unrecorded oil impacts could be located and the areas with a greater possibility to be impacted in the future.

Table A3
Social Development index in 1990, 2001 and 2010. Adapted from Larrea, 2017.

Area	Zone	1990	2001	2010
Urban EAR	**Oil**	47.6	55.3	64.1
	No Oil	58.3	64.8	72.5
Rural EAR	**Oil**	40.4	44.9	53.0
	No Oil, but other activities	41.9	47.0	55.8
	No activities	31.1	35.6	42.3

Table A4
Regression analysis statistics for oil impacts in productive oil blocks.

Years of production until 2020 vs all oil impacts density	
Intercept	−0.41663
β Coefficient	0.02382
β p-value	3.95e-05
R^2	0.4149
Residual Std. Err.	0.3178
Correlation	0.644117
All oil impacts density vs % of Urban elements in 2020	
Intercept	0.13500
β Coefficient	0.15126
β p-value	0.00168
R^2	0.2689
Residual Std. Err.	0.3552
Correlation	0.5185467

3.4. The multiple injustice: Should climate justice include fossil fuel extraction territories?

As stated by the 2018 IPCC Report, the goal is not to exceed the 1.5 °C global warming limit to avoid the worst of climate change's consequences (Rogelj et al., 2018). Hence, global GHG emissions should be drastically reduced to achieve this objective. With this in mind, it is clear that the majority of the world's fossil fuel supplies cannot be burned, so most should remain unburnable (Codato et al., 2023; McGlade & Ekins, 2015). A phasing out from fossil fuels has been identified as a significant strategy to reduce GHG emissions and to limit warming to 1.5 °C.

The analyses provided in this study uncover a multiple injustice: on the one hand, these communities are oil producers, but they are not direct beneficiaries of the incomes from fossil fuel extraction, and on the other hand, the impacts of oil extraction affect the same territories with environmental and social impacts, violating the right to live in a clean, health, and safe environment (Figs. 11–12). Moreover, the effect of climate change, even though it is not specifically investigated in those areas, might have a drastic impact on these populations, especially in the Global South (Parry et al., 2007) and, in the current case, if adaptation strategies are not provided by the Ecuadorian government.

Bearing this in mind, the fair and equitable discourse of climate justice should also intersect the injustices of these territories. As mentioned in the introduction, climate justice mainly places the world into two dimensions. However, a third dimension is less taken into account; it includes those territories and communities that are, at the same time, the sources of fossil fuel extraction but not the beneficiaries of the oil incomes and who bear the costs of living in a polluted environment. Moreover, in most cases, this group is composed of populations located in remote areas—mainly of indigenous people, peasants, and economic migrants—with a high biodiversity within tropical ecosystems, such as our case study (Chamorro et al., 2013; HRC, 2022).

Ecuador and its EAR is a paramount example of this multiple injustice: oil exploitation carried out in this developing country made it dependent on the foreign market and foreign investment. Moreover, oil, as a nonrenewable resource, made Ecuador dependent on new resource discoveries and oil companies. Alternatives that could revert this situation and improve the well-being of the EAR territories, such as improving basic services, environmental thinking diffusion at the national and local levels, and more sustainable economic alternatives, must come from global interests (Alarcón, 2022; Kimerling, 2006).

Thus, defining this third dimension in the climate justice discourse could also help scholars, stakeholders, and policymakers in framing clear, equitable, and fair phasing out of fossil fuel strategies (Cha, 2018.). Indeed, different solutions have already been suggested, such as enabling "a just transition for workers and communities," providing "social protection" for workers and their families, or first decreasing fossil fuel extraction in areas where there are fewer social costs (Muttitt & Kartha, 2020; UNFCC, 2016). However, a deeper analysis should be provided to identify those communities and territories that suffer from this multiple injustice.

Finally, it is important that climate justice focuses on a multiscalar approach by integrating the local with the global and international scales. By doing so, different peculiarities of territories might be illuminated, as, for example, has been shown in our case study.

4. Conclusion

In our case study, we have analyzed EAR, an urbanized territory defined as an urban jungle where citizens are overtaking rural inhabitants. Our results show a strict relationship between oil expansion and urban growth, underlining how the human well-being of these communities is worse compared with the part of EAR not engaged by oil extractive activities. Finally, the results showed a high density of recorded oil spills, oil pits, and gas flaring sites in historically productive blocks, increasing the socio-environmental impacts for these territories.

In conclusion, our results show a multifold injustice for these fossil fuel extraction territories because they are not the beneficiaries of fossil fuel revenues and strongly affected by the socio-environmental impacts of oil extraction. Hence, climate justice should embrace these territories in its perspectives by defining these actors as a priority group in the climate justice discourse. By doing so, scholars, stakeholders, and policymakers might frame clear and just phasing out of fossil fuel strategies.

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.

Annex

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