Special Issue:
Society and Volcanology (SOVOL)

A NEW IMPETUS IN "GEO-LITERACY" IN THE NATIONAL VOLCANIC PARKS OF COSTA RICA AND SURROUNDING SECTORS FOR BETTER RISK MANAGEMENT

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ABSTRACT

In Costa Rica, all the large volcanoes have been converted into national parks, which has limited human occupation and productive activities in its closest areas. The country has been promoted worldwide as an important tourist destination due to its biodiversity and commitment to conservation, increasing tourism and people's exposure to different volcanic hazards. Public universities and the National Commission for Risk Prevention and Emergency Attention (CNE) carry out informative and educational activities for the population. In 2020, the CNE promoted a 'geoliteracy' campaign, through the design and installation of signs with preventive and geo-educational information on volcanoes in Spanish and English. As of December 2022, more than 250 signs had been installed in collaboration with National Parks, the Costa Rican Electricity Institute, communities, private companies, the tourism sector, and the Community Aqueduct and Sewer Management Associations. These actions have generated a sense of empowerment and belonging in the actors involved. The actions are linked to the National Law on Emergencies and Risk Prevention, the National Risk Management Policy (2016-2030) and the National Risk Management Plan 2021-2025.

KEYWORDS

Risk management; Tourism; Volcanic national parks; Geoliteracy; Information design; Costa Rica

UN NUEVO IMPULSO A LA "GEOALFABETIZACIÓN" EN LOS PARQUES NACIONALES VOLCÁNICOS DE COSTA RICA Y SECTORES ALEDAÑOS PARA UNA MEJOR GESTIÓN DEL RIESGO

RESUMEN

En Costa Rica, todos los grandes volcanes se han convertido en parques nacionales, lo que ha limitado la ocupación humana y las actividades productivas en sus áreas más cercanas. El país se ha promocionado a nivel mundial como un destino turístico importante por su biodiversidad y compromiso con la conservación; aumentando el turismo y la exposición de las personas a los diferentes peligros volcánicos. Las universidades públicas y la Comisión Nacional para la Prevención de Riesgos y Atención de Emergencias (CNE) llevan a cabo actividades informativas y educativas para la población. En el 2020, la CNE impulsó una campaña de geoalfabetización, mediante el diseño e instalación de rótulos con información preventiva y geo-educativa sobre los volcanes en español e inglés. Hasta diciembre de 2022, se habían instalado más de 250 rótulos en colaboración con Parque Nacionales, Instituto Costarricense de Electricidad, comunidades, empresas privadas, el sector turístico y las Asociaciones Administradoras de Acueductos y Alcantarillados Comunales. Estas acciones han generado un sentido de empoderamiento y pertenencia en los actores involucrados. Las acciones están vinculadas a la Ley Nacional de Emergencias y Prevención de Riesgos, la Política Nacional de Gestión de Riesgos (2016-2030) y el Plan Nacional de Gestión de Riesgos 2021-2025.

PALABRAS CLAVES

Gestión del riesgo; Turismo; Parques nacionales volcánicos; Geoalfabetización; Señalética; Costa Rica

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DOI:
https://doi.org/10.55467/reder.v7i2.121

RECEIVED
5 September 2022

ACCEPTED
20 April 2023

PUBLISHED
1 July 2023

Recommended citation (APA style):
Alvarado, G.E., Alpízar, Y., Araya, R., Esquivel, L. & Sánchez, B. (2023). A new impetus in "geo-literacy" in the national volcanic parks of Costa Rica and surrounding sectors for better risk management. *Revista de Estudios Latinoamericanos sobre Reducción del Riesgo de Desastres REDER, 7*(2), 6-18. https://doi.org/10.55467/reder.v7i2.121

Journal of Latin American Studies on Disaster Risk Reduction REDER

Revista de Estudios Latinoamericanos sobre Reducción del Riesgo de Desastres REDER

Design: Lupe Bezzina

INTRODUCTION

All the larger volcanoes (stratovolcanoes, andesitic shield volcanoes) of Costa Rica, including historically active (1700-2022), dormant, or extinct volcanoes, began to be declared national parks gradually since 1955. This stopped human occupation and extension of productive activities not in accordance with the potential of land use, particularly agriculture and livestock, as well as possible commercial and industrial activities at the top of these sectors. Several of these national parks have been exposed to the eruptive activity of one of the five historically active volcanoes. At the end of the 20th century, Costa Rica began to promote itself worldwide as an important tourist destination due to its great biodiversity and its vocation for conservation. Now, Costa Rica is considered globally as a tourist mecca, and clearly, this caused the visitation to the different volcanoes of the country to increase and, therefore, the exposure of people to the different volcanic hazards. Tourism is positioned within the second entry of foreign currency for Costa Rica, hence its importance, but at the same time its vulnerability by depending on a somewhat volatile environment in the face of external or internal adversities that can alter it in a surprising way (Alvarado, 2021).

If it is taken into account that approximately one million tourists in Costa Rica visit the volcanic parks and neighboring areas each year, and this high rate of visitation increases their exposure to certain geohazards. In fact, the tourist, livestock, and agricultural economy of Costa Rica was affected by eruptions of the Turrialba volcanoes (particularly between 2014 and 2017) and Poás (2017), as well as by the global emergency due to the pandemic of COVID-19 (2020-2022). In this framework, the project of preventive and geo-informative labeling was born within the National Commission for Risk Prevention and Emergency Attention (CNE), as a means of education, prevention and, indirectly, of economic reactivation by providing tourists with first-hand information about volcanoes and their details. Previously, Alpízar (2018) had highlighted the importance of preventive signage in areas with volcanic influence and began a process of rapprochement with one of the communities, precisely the one that today has benefited from the project that has become a reality.

Volcanological and geo-tourism framework

The geographical location of Costa Rica, between two continental masses (North and South America) and two oceanic masses (Pacific Ocean and Caribbean Sea), together with being limited by four tectonic plates (Caribbean, Panama microplate, Coco and Nazca), with two convergent boundaries and a transform fault, makes it a region of wide biodiversity and geodiversity, due to the conjunction of geological and climatic processes prevailing for millions of years, which have shaped a complex landscape and ecological mosaic (Figure 1).

Approximately 50 percent of the Costa Rican territory is made up of volcanic rocks of Cretaceous to Quaternary age. There are two mountain ranges with active volcanoes (Guanacaste and Central) and others with extinct Neogene volcanoes (Miocene-Pliocene), although some are from the Lower Pleistocene (Tilarán, Talamanca, Coco, and Montes del Aguacate ranges). It has five historically active volcanoes (Rincón de la Vieja, Arenal, Poás, Irazú and Turrialba) and so far, only the Holocene eruptive activity of the Miravalles, Chato, Hule and Barva volcanoes has been verified (Alvarado, 2021).

The explosive activity of stratovolcanoes undoubtedly represents a threat to the population, putting exposed communities and even properties located hundreds of kilometers away at risk, hence the importance of geo-literacy. In fact, virtually all types of volcanic hazards can occur, including seiches in crater lakes and hydroelectric dams with nearby volcanoes, as well as eventual outgassing in the form of limnic eruptions (e.g., CO^2 in certain deep crater lakes). For this reason, a synoptic figure (both in Spanish and English) was prepared that has been distributed in reports and soon as geo-informative signs, showing the main volcanic hazards, both direct and indirect (Figure 2).

Given the conditions of bio and geo-diversity, access roads and facilities (drinking water in 91.2 percent of the territory, 99.4 percent electricity and telephone coverage, health services) and lodgings of various prices, have turned Costa Rica into a world-renowned tourist destination, with a total of approximately one million annual visitors, who can, on the same day, have breakfast on the Pacific coast, have lunch in a volcanic region over 3,000 m high, and dine with views of the Caribbean sea (Alvarado, 2021).

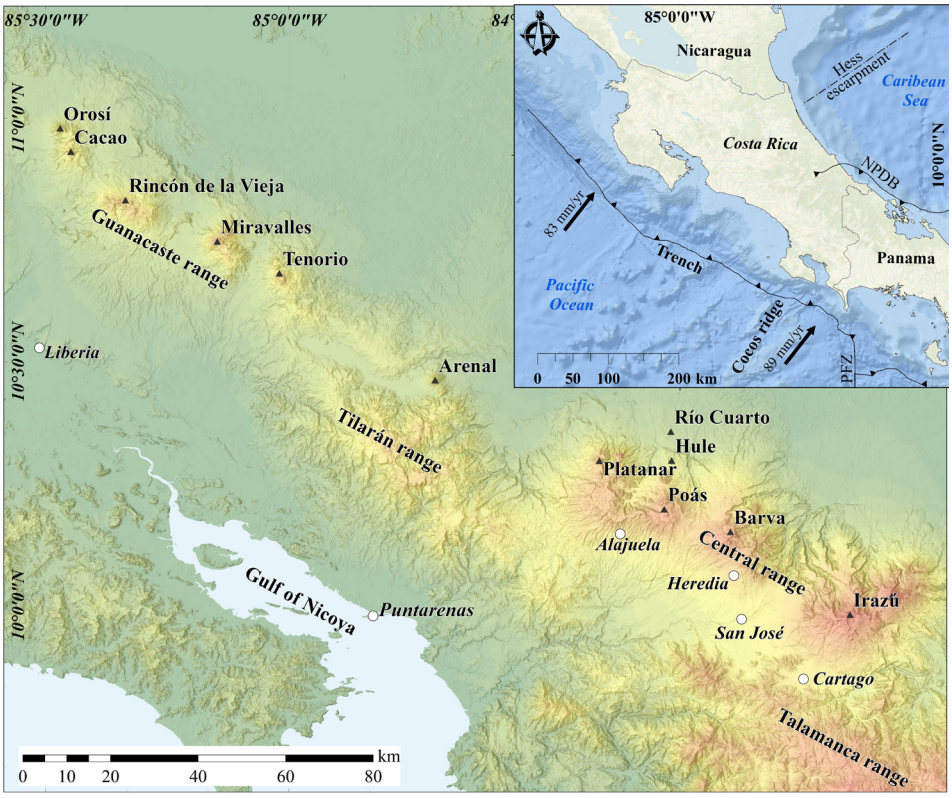

Figure 1. Geological and tectonic framework of Costa Rica showing the main volcanoes mentioned
Source: Authors, 2023.

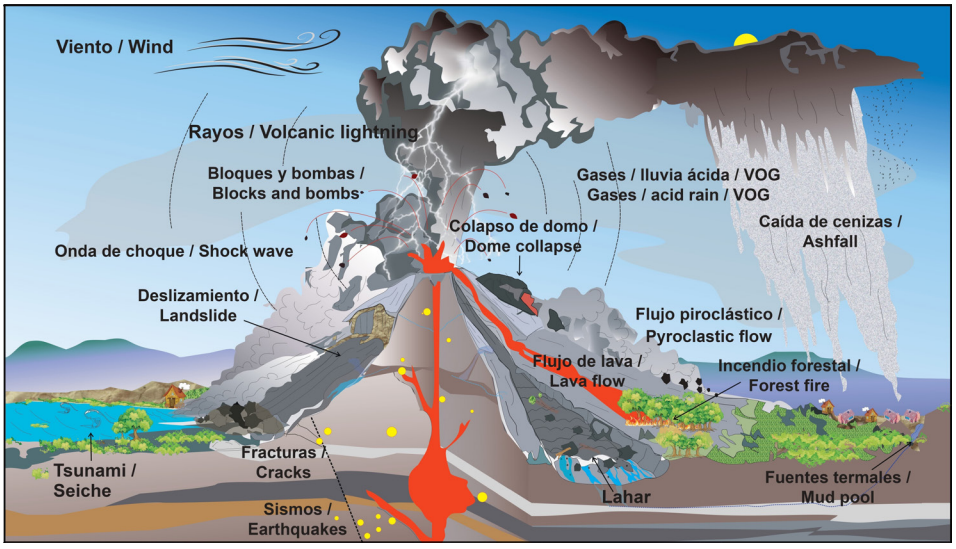

Figure 2. Example of signage with geo-information on the main types of volcanic hazards that can occur in Costa Rica
Source: Authors, 2023.

Table 1 presents an approximate annual visit of national and foreign tourists to the volcanic national parks in Costa Rica or parks with Upper Pleistocene-Holocene volcanic structures, a figure that varies markedly from year to year, and does not show those tourists who visit the areas surrounding the volcanoes or those who enter illegally on unauthorized trails.

National Park	2019 (pre-pandemic)			2021 (towards the end of the pandemic)		
	residents	non-residents	Total	residents	non-residents	Total
Arenal Volcano	27,209	92,592	*119,801*	26,759	42,160	*68,919*
Braulio Carrillo	28714	5205	*33,919*	3396	1479	*4875*
Guanacaste	-	20	*20*	-	-	-
Coco Island	4322	8653	*12,975*	3140	9536	*12,676*
Juan Castro Blanco	133	11	*144*	55	-	*55*
Rincón de La Vieja	25,861	77,601	*103,462*	19,770	28,008	*47,778*
Irazú volcano	263,359	88,675	*352,034*	164,685	28,218	*192,903*
Poás Volcano	60,817	86,413	*147,230*	74,877	35,144	*110,021*
Tenorio volcano	59,431	88,631	*148,062*	54,108	69,524	*123,632*

Table 1. Visitation to volcanic parks in Costa Rica in 2019 and 2021
Source: ITC (2021, http://www.sinac.go.cr/ES/transprncia/Paginas/estadisticas.aspx).

In addition to tourist visitation, Costa Rica occupies a privileged position by having volcanoes (complex stratovolcano type and andesitic shields) with an access road to the main crater itself (see table 2), either by simple vehicle (Poás and Irazú volcanoes) or by 4x4 vehicle (Turrialba, Barva and Cacao volcanoes). Flat volcanic structures, as ignimbrite calderas, or small volcanoes or monogenetic cones (including maars) are excluded from this table. In fact, through a consultation of tourism books, volcanological observatories and volcanologists, journalists, and other sources of information, it was possible to establish that worldwide, approximately there are at least 33 stratovolcanoes (7.33 percent of the total worldwide, excluding calderas and monogenetic volcanic fields), gathered in 13 countries, which have at least one vehicular access route to the summit crater. Of these, 16 (3.55 percent) can be reached by simple vehicle or bus, while the remaining 3.77 percent (17 volcanoes) can be reached by a four-wheel drive vehicle. This offers an enormous advantage for volcanological studies (including volcanic monitoring), but also increases the vulnerability of human lives and existing infrastructure, particularly in volcanoes. However, the access is also facilitated in case that emergency attention is needed for tourists or personnel, whether they are volcanic emergencies or of another nature.

Country	Total volcanoes (percentage of total worldwide)	Access by simple vehicle or bus	Access by 4x4 vehicle
Costa Rica	4 (0.9%)	2	2
USA	4 (0.9%)	2	2
Japan	4 (0.9%)	3	1
El Salvador	3 (0.66%)	1	3
Nicaragua	3 (0.66%)	1	2
Panama	3 (0.66%)	1	2
Colombia	3 (0.66%)	0	3

Table 2. Countries in which there are at least 3 large volcanoes with vehicular access to the crater
Source: Authors, 2023.

Even though there is a large population living around the volcanoes, so far, the number of deaths due to volcanism has been insignificant compared to other countries of the Central American isthmus and neighboring countries such as Mexico and Colombia (Tables 3, 4 and 5). The fact that no catastrophic volcanic event has occurred to date may be due to the fact that by declaring the main volcanoes national parks, land use was regulated and a use more in line with its potential was promoted, avoiding the settlement of communities in the areas closest to the volcanic cones; but also because there is a very solid volcanology group that advises the National Risk Management System and works in coordination with the institutions that comprise it, communities, private companies, organized civil society, and the media. Statistics show that: a) the principal cause of death in Costa Rica by volcanic activity is similar as other countries (i. e., pyroclastic flows, lahars and ballistic), and b) it is so far more likely to die from other causes (diseases such as cancer or COVID-19) than from volcanism or even earthquakes.

Period/geographical area	1700-2021/ World	1900 - 2021/ World	1700 - 2021/ Costa Rica
Primary cause (for given period)			
Pyroclastic density currents	62,000 (23.4%)	36,800 (48.4%)	80 (77.7%)
Tephra fall and ballistics	11,000 (4.1%)	3,000 (4.0%)	3 (2.9%)
Volcanic gases	2,000 ((0.75%)	1,900 (2.5%)	-
Lava flows	1,000 (0.35%)	100 (0.1%)	-
Faulting and earthquakes	-	-	-
Cortical deformation and crack formation	-	-	-
Secondary cause (for given period)			
Post-eruptive starvation and disease	89,400 (34%)	3,200 (4.2%)	-
Tsunamis and seiches	54,200 (20.4%)	400 (0.5%)	-
Lahars	45,000 (17%)	28,400 (37.4%)	20 (19.4%)
Shock waves	-	-	-
Ray	-	-	-
Acid rain	-	-	-
Other or unknown	-	2,200 (2.5%)	-
Total	**264,600**	**76,000**	**103**
Average number of deaths per year	***824***	***628***	***0.3***

Table 3. Comparison of fatalities in Costa Rica due to volcanic causes (direct and indirect) with the rest of the world
Source: Authors, 2023, based on Aguilar and Alvarado (2014); UNDRO-UNESCO (1985); Tilling (1989); Tanguy et al. (1998).
Note: Since 1700 there is a better historical record at the national level, because between 1500 and 1700 there is no documentary record of a volcanic eruption, from the historical point of view. However, exist some radiocarbon ages that indicated possible volcanic eruption after 1500 with no written record.

Volcano	Date	Deaths	Injuries	Cause of damage	Reference
Irazú	December 9-10, 1963	~20	250	Lahars	Alvarado & Schmincke (1994)
Irazú	Prior April 1964	-	2	Ballistic	Alvarado (2021)
Irazú	April 12, 1964	2	50	Ballistics	Alvarado (2021)
Arenal	July 29, 1968	~70	-	PDC/Ballistics	Melson & Sáenz (1968)
Arenal	July 31, 1968	~8	-	PDCd	Melson & Sáenz (1968)
Arenal	June 17, 1975	-	1	PDCd	Van der Bilt et al. (1976)
Arenal	July 6, 1988	1	1	Ballistics	Aguilar & Alvarado (2014)
Arenal	August 28, 1993	-	1	PDCc	Aguilar & Alvarado (2014)
Arenal	August 23, 2000	2	1	PDCd	Aguilar & Alvarado (2014)

Table 4. Details of the number of deaths and their origin at the national level (until 2021)
Source: Authors, 2023.
Note: PDC=Pyroclastic Density Currents (c and d); PDCd=PDC dilute or pyroclastic surges, PDCc=PDC concentrate or pyroclastic flows. In most of the cases, the PDC at Arenal were both (c and d), but the cause of kill was, in most of the cases, by surges.

Mortality	Volcanism	Seismicity	Traffic accidents	Criminality	Cancer	COVID-19
Deaths/year	0.2 - 0.3	1.4 - 2.2	688 (2017)	571 (2020)	5500 (2021)	7400 (2021)
Deaths/day	0.0008	0.006	1.8	1.6	15	20*

Table 5. Annual and daily mortality in Costa Rica due to the main natural and anthropic causes and its comparison to volcanism and seismicity
Source: Authors, 2023.
*At the end of August 2022 was about 5 people.(including lateral blast).

Geo-literacy in Costa Rica

If you wanted to briefly cover volcanology education in Costa Rica in a simplified way, then you could propose several stages based on previous research (Alvarado and Patino; 2017; Alvarado, 2021; Alvarado et al., 2021). From now on, *geo-literacy* will be understood as the training process aimed at the population (permanent and transitory), government and private organizations, as well as authorities and decision makers of a certain area with particular geological characteristics. This

includes the geo-dynamic processes that act on the environment, in our case, including volcanism, geomorphology and natural hazards. It should also focus on promoting prevention and increasing resilience.

- *Proto-educational stage by foreigners (19th century)*: This phase corresponds mainly to the second half of the 19th century, when various foreign naturalists and geologists (mainly of German, Swiss, French, U.S.A and Danish nationality) began to investigate volcanoes (their geographic, geomorphological features, volcanic activity, hot springs and fumarole temperatures, basic chemical, petrographic and mineralogical aspects). The results of his research were published in foreign languages and magazines. In general, at that moment, there was no education focused on nationals regarding geosciences and volcanoes in particular.
- *Educational stage by nationals and foreigners (first half of the 20th century)*: During this period, the first national naturalists began to form, accompanied by foreign celebrities. Much of the research results at this time were published in Spanish in local magazines and included in geography books. It can be said that a stage of geo-education was already beginning. High school teachers include geological and mineralogical aspects in their classes, as well as field trips.
- *Beginning of the systematic study and teaching of geosciences (second half of the 20th century)*: The activity of the Irazú (1963-1965) and Arenal (1968-2010) volcanoes with destruction and death triggered the first two declared emergencies in Costa Rica due to volcanic eruptions. At the same time, these eruptions encouraged the arrival of foreign volcanologists (Japanese, U.S. North American, Belgian-French) who worked together with national geologists and engineers. Newspaper reports and press conferences then became daily aspects, as well as radio bulletins. Volcanic activity had affected, to a greater or lesser degree, more than 60 percent of the country's population in just the 1960s. All this motivated not only the training of professionals in geology-volcanology, but also the creation of institutions such as the Civil Defense in 1969 (later renamed the National Commission for Risk Prevention and Emergency Attention, CNE), the Central American School of Geology (1969), the National Seismological Network (1982) and the OVSICORI (1984). From that moment, the volcanological work developed during the second half of the 20th century began to be disseminated in a broader and more generalized way. Courses such as Volcanology, Volcanic Geomorphology and Volcanic Surveillance were included in university academic programs.
- *Mass broadcasting of volcanology (first half of the XXI century)*: Social networks (email, WhatsApp, Facebook, Instagram, Twitter and TikTok) promoted a massive dissemination of volcanic activity and information alluding to volcanism in all corners of the country, from official reports to tourist promotion and photographs. People began to inform themselves and, in turn, researchers began to receive information from "volcano observers", mostly photographs, videos, reports of ash fall, smell of gas and eruptions. This information has turned out to be useful for the elaboration of the official reports of volcanic activity. On March 13, 2015, the webcam located at the top of Turrialba captured a major eruption, so the OVSICORI decided to share the video on Facebook; thus, people were able to see for the first time in Costa Rica, an erupting volcano in real time through social networks.

METHODOLOGY

A brief description of the methodology followed for the development of the research is presented (Figure 3). Initially, a rapid diagnostic process of the areas to be intervened was carried out, and in this way the need to carry out the project was identified. Subsequently, reference documents were consulted about experiences in other countries as well as and basic guidelines on vertical signage. In order to achieve a sense of ownership of the project by the communities, a community consultation process was carried out, in which input was sought from community leaders and organizations such as Development Associations, Aqueduct and Sanitary Sewer Administrator Associations (ASADAS), tourism chambers, staff of the National System of Conservation Areas (SINAC), among others. Examples of other countries in which similar projects had been carried out were reviewed, and the search for funds to make the signs began. Subsequently, since a state actor was involved, it was necessary to carry out a bidding process to choose the company in charge of printing the signs.

Based on technical-scientific information, the design process and layout of the signs began, ranging from the most basic preventive signs (project started as an idea at the end of 2019) (Figure 6), to arts with information and illustrations (the project started in 2020 and continue to 2023) detailed about the geo-site and, if it exists, the associated volcanic hazard (Figure 7). Once the artworks were designed, they underwent a review of form and substance before being sent to print. Prints are made of a rigid, corrosion-resistant material to ensure durability. Finally, the installation logistics were placed in the hands of each community, both the materials and the labor to place the signs in their destination places, as this was thought to reinforce the feeling of appropriation, and that the signs were perceived by the community as something "of their own that is worth taking care of", and not as something that someone else placed there.

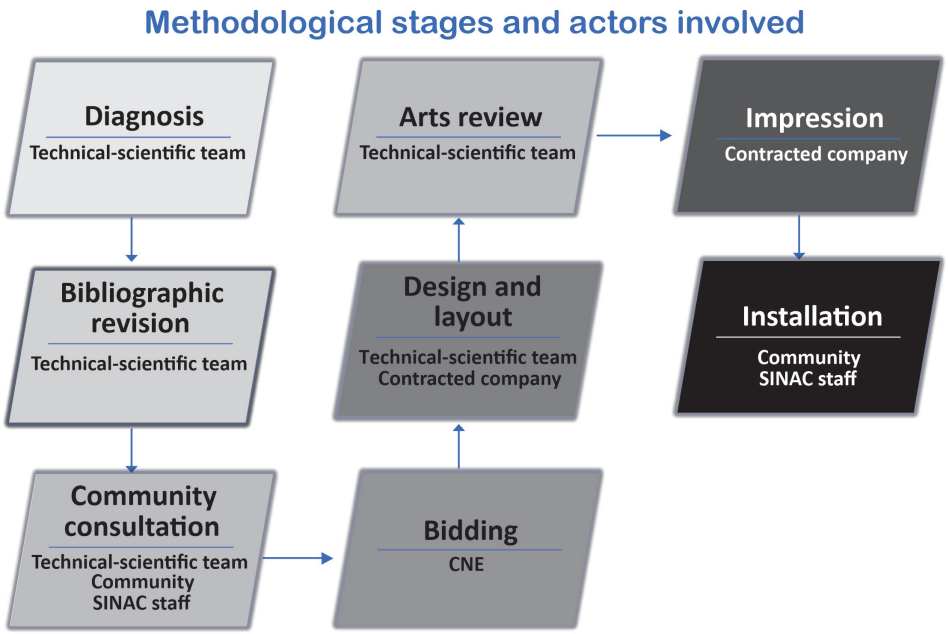

Figure 3. Flowchart of the methodology followed to carry out the research of preventive and geo-tourist signs
Source: Authors, 2023.

RESULTS

Improvements in risk management since 2017

After several months of relative calm, the Poás volcano began to show minor and variable changes in activity since January 2017, without breaking its normal pattern of activity. But on April 12 at 6:49 pm, a phreatomagmatic eruption that lasted about 40 minutes was recorded, consisting of water, sediments, rocks up to half a cubic meter, steam and gases directed towards the WSW of the crater. On this day, Poás would begin its fourth most important eruptive period in its short-written history, where the previous relevant eruptive periods occurred in 1834, 1910, 1953-1955. All this led to the closure of the Poás Volcano National Park as of April 13. The closure of the national park was maintained for a period of approximately 1 year and 4 months (until August 31, 2018). This motivated the construction of 5 protection booths or volcanic anti-ballistic shelters, which was carried out between July 2 and August 24, 2018, as well as the more controlled entry of the number of visitors (Alvarado et al., 2021). Three more anti-ballistic shelters were built in 2023.

Previously, the Turrialba volcano began its current eruptive period on January 5, 2010, but it intensified from October 29, 2014, to the present (the last ash release was on August 5, 2020). For all of the above and following the example of the Poás Volcano National Park, the construction of 7 anti-ballistic shelters was carried out as a measure to minimize the volcanic risk. Their construction was undertaken by the Costa Rican Institute of Electricity (ICE), where they were built and assembled on a trial basis in May 2018. After obtaining the respective permits and administrative procedures by the National Technical Secretariat (SETENA) and SINAC, their construction on the Turrialba volcano began on November 13, 2018, and ended on December 14 of that year. The shelters were made following the model of the "bunker" that was built more than 57 years ago in Irazú (Alvarado et al., 2021).

Beginning of the labeling process

Parallel to the infrastructure improvements, many conferences were given to tour guides, park rangers and public (estimated at several thousand people) in different volcanoes and regions, to clear up doubts and train staff on volcanism. Also, to improve the risk management, public universities and the National Commission for Risk Prevention and Emergency Attention (CNE) monitor the different volcanoes in the country and have developed a series of informative and educational activities for the population, such as workshops, informative folding documents, posters, and brochures, among others (Alvarado, 2021; Alvarado et al., 2021).

Although volcanic geo-literacy has always been necessary, it was not until 2020 with the closure of borders, when the tourism sector was forced to subsist almost entirely due to the contribution of nationals, that the importance of potentiating certain areas became more evident. geographic with remarkable characteristics. Other aspects that motivated the informative and preventive labeling were: a. the lack of basic informative signage for areas of volcanic influence and the deterioration of some preventive signs, b. the increase in volcanic eruptions that, by possessing undeniable scenic beauty in conjunction with the accessibility of some sites, increased vulnerability, and, c. the same social networks were also factors that led in recent years to an evident increase in recreational walks with illegal entry (sectors restricted due to their danger) and uncontrolled national and foreign tourists to areas of high hazard, coupled with the difficulty and costs of possible rescues.

The intense geo-literacy campaign consisted of the design, layout and installation of aluminum signs (resistant to acid rain and inclement weather in the tropics) with preventive and educational information in Spanish and English, containing maps, photographs, historical drawings and warnings, among others. To this was added in parallel an intense campaign of conferences to residents, park rangers, tour guides and personnel linked to emergency care (Red Cross, Municipal Emergency Committees, Local Emergency Committees).

Until December 2022, 7 volcanic national parks have been labeled (in chronological order: Poás, Turrialba, Irazú, Rincón de la Vieja, Barva and Miravalles and protected areas (Hule and Río Cuarto maars and the Congo volcano), as well as in the buffer zones of the sectors surrounding the national parks and neighboring communities (Pasquí-Las Cazuelas Volcanic Field; La Central, Dos Ríos, Gavilán, Buenos Aires, Bajos del Toro) and even sectors close to access trails on the slopes of volcanoes (see Table 6 and Figure 4).

More than two hundred bilingual signs (Spanish/English) have been installed so far, with the collaboration of the National System of Conservation Areas (SINAC), the Costa Rican Institute of Electricity (ICE), communities, private companies, the tourism sector and Administrative Associations of Communal Aqueduct and Sewer Systems (ASADAS), which has generated empowerment and a sense of belonging and importance in all organizations and the community in general.

National park	Preventive signs (90*60 cm)	Geo-informative signs (244*122 cm)	Total
Irazú volcano	45	17	62
Turrialba volcano	22	16	38
Poás volcano	26	8	34
Rincón de la Vieja volcano	30	31	61
Arenal volcano	11	11	22
Barva volcano	20	4	24
Miravalles volcano	0	20	20
Total	**154**	**107**	**261**

Table 6. Labeling of the volcanic threat, geological information, and preventive messages in volcanoes of Costa Rica, December 2022
Source: Authors, 2023.
Note: Includes data between 2020 and December 2022.

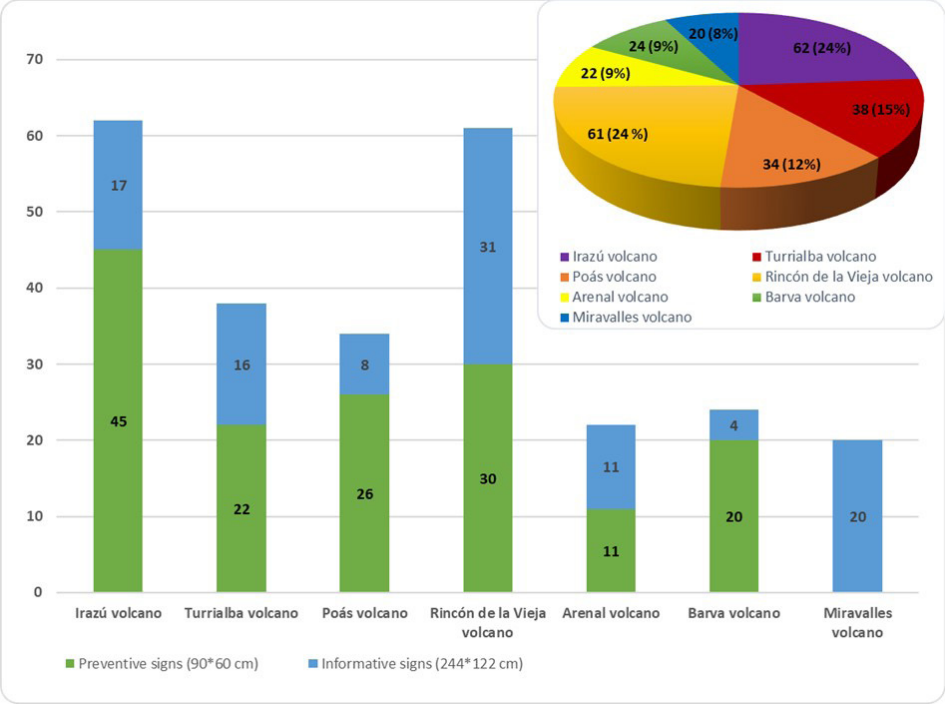

Figure 4. General distribution of the signs (preventive and geo-informative) placed by volcano (absolute values and percentages)
Source: Authors, 2023.

Labels or signs are grouped into two types:

a. *Geo-informative signs*, with relevant geological and volcanological aspects of the volcano, its degree of present and past eruptive activity, including direct examples in the field of types of volcanic hazards, among others. The labels include information about the volcano (name, synonymy, toponymy, historical and prehistoric activity, types of hazards, secondary activity, protection zones), examples of geo-hazards (lava flows, landslides, volcanic debris avalanches, pyroclastic deposits, impact craters, etc.), morphologies (craters, secondary cones, ignimbrite calderas, avalanche calderas, lava flows, hummocks in volcanic debris avalanches), and age stratigraphic sections with radiocarbon ages, among many other examples (Figure 5).

b. *Preventive signs*, with warnings for tourists that they are entering an area with volcanic activity and potential hazard due to landslides, lahars, falls or volcanic eruption. Also included are do not enter and evacuation routes (Figure 6).

Figure 5. Several preventive signs placed in volcanic influence areas
Source: Authors, 2023.

Figure 6. Examples of signs posted at some interest places (illustrative character images)
Source: Authors, 2023.
Note: Many tourists take pictures next to the signs and they are even posted on social networks, a positive sign that they are being consulted and that they bring a sense of identity to the region.

DISCUSSION

Guimarães et al. (2021) emphasize that a series of actions should be promoted to reduce vulnerability and increase resilience, such as creating accessibility to vital infrastructure and the existence of redundancy, carrying out hazard and risk studies, implementing early warning systems, as well as development of emergency plans and promotion of educational activities. Precisely, all the above, including an improvement in communication routes, together with the updating of volcanic hazard studies, and an active promotion of education through conferences, training for tourist guides and park rangers, informative and preventive signage, have been carrying out frequently and intensely in the surroundings of the Rincón de la Vieja volcano, particularly by the CNE, UNA and ICE, at least during the last five years.

Equally interesting are the results of Nieto-Torres et al. (2021) and Guimarães et al. (2021), who established a new methodology for positioning volcanic hazard and risk, applied to Latin America, based on a series of parameters to estimate, and integrate volcanic hazard, exposure, and vulnerability as factors that increase risk and resilience. reduces. There they analyze 123 volcanoes in Latin America (see table 6). Within them, the Costa Rican volcanoes, Irazú and Rincón de la Vieja, are positioned within the 10 most hazardous, while in terms of exposure, Irazú is within the 15 highest. But if it is analyzed in terms of vulnerability (i.e., lack of information, lack of critical infrastructure, social vulnerability, etc.), the Costa Rican volcanoes studied are located within a very similar range and with a vulnerability value among the lowest in Latin America, surpassed only by several volcanoes located in uninhabited places.

Similarly, most of these volcanoes (except for Miravalles) are among the 12 most resilient in Latin America, as they have real-time surveillance systems, education strategies, simulation exercises, emergency, and contingency plans. If the risk is analyzed as the product of H x E x V, since our volcanoes have a low vulnerability, then the risk is quite low, with only Irazú among the 40 most hazardous volcanoes. But if resilience is included, which significantly lowers risk, Arenal, Irazú and Poás are among the six volcanoes in Latin America with the highest positioning in risk reduction strategies and all the Costa Rican volcanoes analyzed gave a fairly low risk (see Table 7).

Volcano	Hazard (H)	Exposure (E)	Vulnerability (V)	Resilience (R)	H x E x V	Risk: H x E x V/R
Rincón de la Vieja	10	76	110	11	81	108
Miravalles	113	57	101	83	103	93
Arenal	32	23	103	1	51	104
Poás	82	39	109	5	94	113
Irazú	4	15	107	6	33	88
Turrialba	23	61	102	10	64	99

Table 7. Weighting of the hazard, degree of exposure, vulnerability, resilience, and volcanic risk
Source: Authors, 2023, based on Guimarães et al. (2021).
Note: Figures according to the analysis carried out by Guimarães et al. (2021) for 123 Latin American volcanoes, where 1 is the highest position and 123 the lowest.

Interestingly, the Pasquí and Las Cazuelas volcanic field (parasitic craters and cones of the Irazú and two lava flow fields) went unnoticed by residents (farmers and ranchers) until, with the start of the pandemic in 2020, a series of geo-informative signs were installed that gave information about their mode of origin and ages. Given that there were restrictions or complications and fears to leave the country, local tourism and picnics soared, reaching the craters of Las Cazuelas with a visitation that exceeded at the beginning that of the volcanic national parks such as Poás and Irazú, and it was a boom at the national level to the extent that it was news in the media (press and television) and social networks. The same thing happened with the placement of other geo-informative signs in other regions of the country, where tourists began to take pictures with them. All of this helped, to a greater or lesser degree, to generate awareness about the passage that surrounds these fields, their method of formation and geological history, as well as the geological hazards (particularly the volcanic ones), even in the long term, in addition to an economic reactivation during and after the pandemic.

It is possible that the number of fatalities from famines and volcanic tsunamis was higher before the 20th century, due to the lack of communication as it is known today. This also hindered

efforts to provide timely international assistance. However, the opposite occurs when it comes to direct volcanic hazards, where the incidence of deaths directly related to eruptions has increased. Despite there being better access to information on volcanic hazards, during the 20th century, areas near active volcanoes, which had even suffered the consequences of volcanic eruptions in the past, began to be populated or repopulated, such is the case of the volcanoes Nevado del Ruiz (Colombia, 1985) and Santa María (Guatemala, 1902), to cite two examples (UNDRO-UNESCO, 1985; Tilling, 1989).

Although the authors consider that talks, community meetings, pamphlets and other types of information are important in geo-literacy, permanently placed bilingual signage benefits not only people who live in a region of volcanic influence, but also tourists and other transient population, not only for its availability, but also for its assertiveness.

CONCLUSIONS

All the actions previously described are linked to the National Emergency and Risk Prevention Law No. 8488, the National Risk Management Policy (2016-2030) and the National Risk Management Plan 2021-2025.

The task of outreach and education to the public carried out by public universities, the CNE and private companies has been vital to raise awareness about volcanism, its virtues and hazard. There are several books, brochures, television documentaries, seminars and conferences that deal with the subject of Costa Rica's volcanoes with various approaches, from merely informative or landscape, to scientific and preventive. There are also several books on the geology of Costa Rica and the volcanoes, the volcanic hazard, as well as the use of volcanic rocks and geothermal energy. Volcanology in recent decades has become a multidisciplinary science that, in addition to promoting the traditional academic line that studies volcanism, also now includes surveillance, volcanic hazards, and geography within the framework of risk management. The extensive program to install geo-informative and preventive signs in volcanic parks, as well as in nearby areas (buffer zones), has been a fundamental complement in risk management.

The foregoing should be implemented not only in other conservation areas that have aspects of geological interest, but also in those places that may have their attractiveness and require protection (outcrops, geo-forms, types of rock particles or deposits, among others) as a geomorphic-site and geo-diversity, or even a candidate to be declared a geological heritage or a future geo-park.

ACKNOWLEDGMENTS

The National Commission for Risk Prevention and Emergency Attention (CNE) paid for the preparation and transportation of the signs. Various entities collaborated with its installation, among several of them, the National System of Conservation Areas (SINAC) with its National Parks, local communities, various private companies, the tourism sector in some localities, in particular, the Rincón de la Vieja (CATURVI), the Costa Rican Institute of Electricity (ICE) and the Administrative Associations of Communal Aqueduct and Sewer Systems (ASADAS), in particular the ASADA of Santa Rosa. We also are in deeply grateful to Pablo Murillo and to Peter Ryan for review the English in the early and last version, respectively. We also thanks for the anonymous referee for their valuable comments.

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