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Volcanic Risk Perception and Coping Strategies from Mounts Cameroon and Nyiragongo Eruptions, Central Africa: A Comparative Analysis

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Abstract

Approximately 2,000,000 people are exposed to volcanic risks in communities situated at the flanks of Mounts Cameroon (MC) and Nyiragongo (MN) volcanoes in Central Africa. This study therefore sought to investigate risk perception from four previous eruptions of MC, namely the 1959, 1982, 1999, and 2000 eruptions; and two previous eruptions of MN: 1977 and 2002. The study was initiated with co-design workshops held with major stakeholders in the cities of Buea and Goma at the flanks of MC and MN, respectively, in 2017, to develop the research objectives for the study. A non-random questionnaire survey was later conducted within 14 and 15 communities in Buea and Goma respectively, on the effects, perceived risks, and coping strategies for the chosen eruptions. Three age groups (18 - 30, 31 - 45 and >45 years) and gender (male and female) were considered. The population at the flanks of both volcanoes cited scientific and indigenous factors to be responsible for eruptions from these volcanoes. At MC and MN, ≥45% of the sampled participants (with a higher female population) perceived that the sampled eruptions posed a very high risk to the population. In terms of the effects, the age group of 18 - 30 was the least knowledgeable. In terms of direct effect on persons, over 90% of participants at MC and MN attested that they were overcome by fear/panic. On measures to cope with any likely eruption, the following order was established at the flanks of both volcanoes: sensitization of

population, use of religious (prayers) and of traditional/indigenous strategies. In terms of future coping strategies, while the males at MC maintained sensitization as the favourite option, 62% of the males at MN opted for traditional/indigenous strategies. The female population at both MC and MN showed a higher preference for religious strategies like prayers.

Keywords

Risk Perception, Mount Cameroon, Mount Nyiragongo, Indigenous, Buea, Goma

1. Introduction

The population (~2,000,000 people) living at the flanks of both Mounts Cameroon (MC) and Nyiragongo (MN), are exposed to the destruction resulting from their eruptions as inevitable and a manifestation of nature's wrath. Thus, they have resorted to using several coping strategies since these eruptions disrupt the socio-economic life and livelihood of the population (Wantim et al., 2018). Volcanic eruptions are usually multi-hazard events where a single eruption is capable of being preceded and accompanied by earthquakes; producing lava flows, tephra and volcanic gases, as has been observed for eruptions at MC (Suh et al., 2003; Wantim et al., 2011) and MN (Baxter & Ancia, 2002; Allard et al., 2003; **Figure 1(a)**, **Figure 1(b)**). A major similarity between these two volcanoes is that they are found just a few kilometers (~12 and 15 km, respectively) from major urban settlement areas (the cities of Buea and Goma, respectively) characterized by destructive lava flows and poisonous volcanic gases ("*mazukus*") as the principal hazards (Ayonghe & Wantim, 2016). Eruptions from these volcanoes have no fixed return period, making them a forgotten threat and this usually results in their eruptions taking the population unaware as was the case during the May 2021 Mount Nyiragongo (MN) eruption (Uwishema et al., 2021; Boudoire et al., 2022). However, taking into account that some volcanic eruptions may last for a long time (decades in some cases) once they begin (e.g. the Montserrat; Wadge, Robertson, & Voight, 2014) and the 2021 La Palma volcanic eruptions in the Canary Islands; Martí, Becerril, & Rodríguez (2022) lasted for 2 years and 85 days respectively resulting in huge losses and damages to the population at its flanks); there is therefore the need for continual scientific advice for policymakers to reduce the risk. This need has been exacerbated in recent times as the human population on Earth has exceeded seven billion, and perhaps placing as many as one billion within 100 km of active volcanoes (Donovan & Oppenheimer, 2016).

Previous studies carried out by Paton et al. (2008), attest that the population living within the immediate vicinity of active volcanoes vary in their perception of risk. According to Donovan, Eiser, & Sparks (2014), an important aspect for those responsible for volcanic emergencies is to understand both the risk perception

within the scientific community and its views about public perception of risks using a public participatory approach to facilitate the integration of scientific and local knowledge. This point was reiterated by Boudoire et al. (2022) in relation to the May 2021 MN eruption that took the population unaware as was the case in 1977 and 2002, despite the volcano monitoring system that had been put in place. Boudoire et al. (2022) highlighted the limits of current high-tech monitoring techniques in volcano crisis management and advocated for the use of efficient communication between scientists, local authorities, major stakeholders, and the exposed communities relevant for information dissemination and preparedness.

Research interest in volcanic risk perception dates back to the 1960s (Lachman & Bonk, 1960; Blong, 1984; Gaillard & Dibben, 2008). The number of studies on public volcanic hazard-related risk perception has significantly increased in the last two decades (Martínez-Torvisco et al., 1997; Davis, Ricci, & Mitchell, 2005; Carlino, Somma, & Mayberry, 2008; Gaillard & Dibben, 2008; Gregg et al., 2008; Jóhannesdóttir & Gísladóttir, 2010; Njome et al., 2010; López-Vázquez & Marván, 2012; Pardo et al., 2015; Bentzen, 2019; Michellier et al., 2020a; Mosuka, 2020; Gomez-Zapata et al., 2021; Cuesta et al., 2022; Niroa and Nakamura, 2022; Nyandwi et al., 2023; Stoffle & Van Vlack, 2022). However, as observed by Gaillard & Dibben (2008) and Njome et al. (2010), most of these studies have been carried out in developed nations. From a psychosocial point of view, risk perception is viewed as a process that is influenced by different factors: personal, social, political, historical, and cultural (López-Vázquez & Marván, 2012). In this study, risk perception addresses the relationship between volcanic hazards and the consequences they can create when they interact with the environments in which people live (Paton et al., 2008).

The most active and hazardous African volcanoes are found along the Cameroon Volcanic Line (CVL; Fitton, 1980) and the East African Rift System (EARS; Ayonghe & Wantim, 2016). Four of these volcanoes: Erta Ale in Ethiopia, Nyamuragira and MN in DR Congo (all in the EARS) and Ol Doinyo Lengai in Tanzania erupted between 2021 and 2022. The 20th century eruptions from MC are better documented and shows the frequency of eruptions as close as a year for some (e.g. 1865 and 1866; 1999 and 2000) and up to 32 years (1922 to 1954) for the longest interval. Estimates made by Bonne et al. (2008) gave a return period of between 11 and 14 years for these eruptions. Despite this, the last eruption at MC was in the year 2000 (Wantim et al., 2011).

This study therefore sought to investigate risk perception from four previous eruptions of MC namely the 1959, 1982, 1999 and 2000 eruptions, and two previous eruptions (1977 and 2002) of MN (**Figure 1**); the effects of these eruptions on the population, and knowledge of coping strategies to enable the community to cope with the cited risks. The objectives of this study are in line with the Sustainable Development Goals (SDG) 11 (SDG Good Practices, 2020), which aims to make cities and human settlements inclusive, safe, resilient and sustainable.

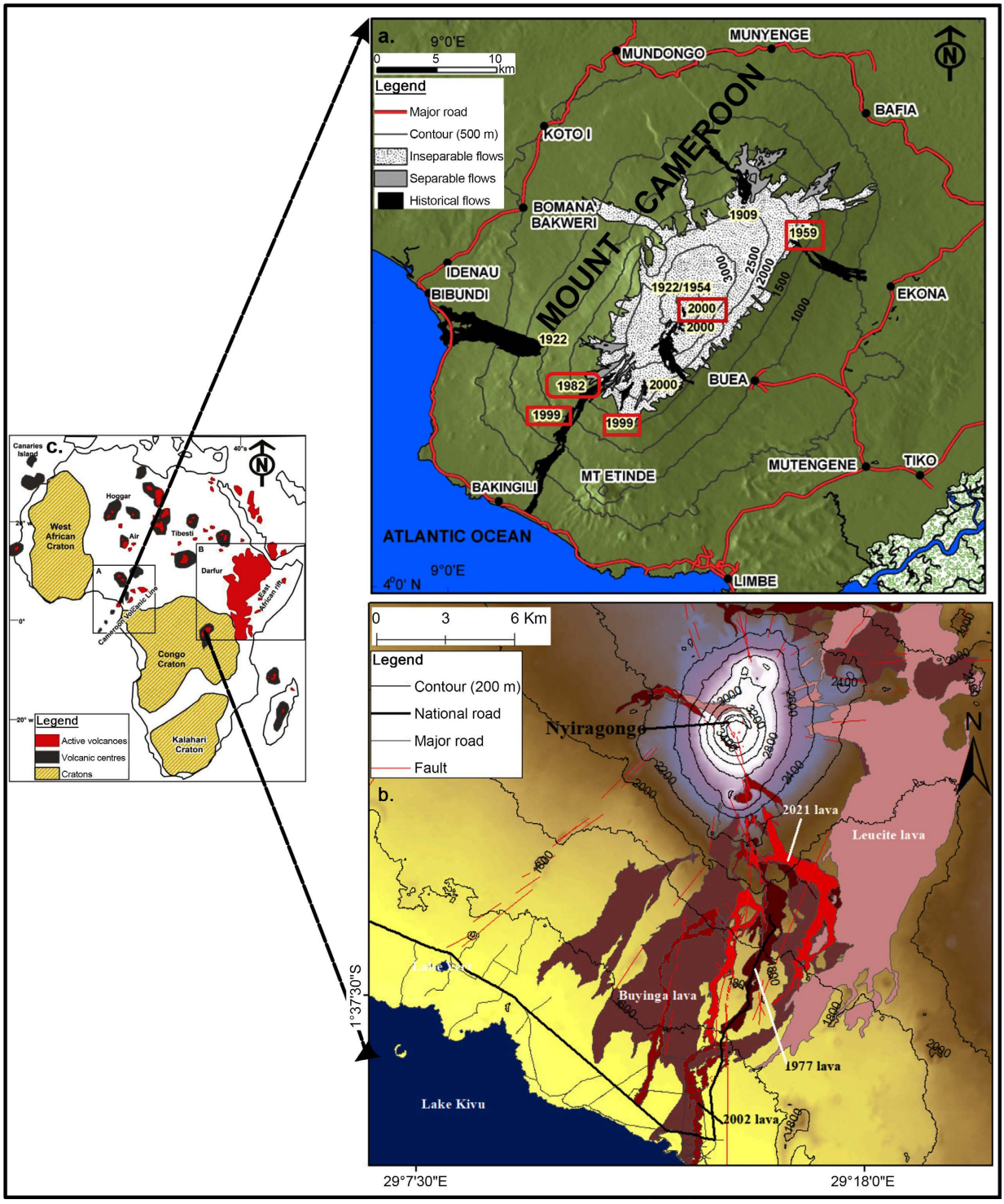

Figure 1. Maps showing (a) Mount Cameroon volcano on shaded relief view of the 90 m SRTM DEM with historical eruptions sites and lava flow fields for the 1959, 1982, 1999, 2000 and others; (b) Mount Nyiragongo volcano on SRTM 30 m DEM showing the lava flow fields of the 1977, 2002, 2021 eruptions; (c) Inset: map of Africa showing the Cameroon Volcanic Line (CVL) and East African Rift System (EARS) adopted from Ayonghe and Wantim (2016).

1.1. Background on MC and MN

MC with an elevation of 4100 m (Ghogomu et al., 1999) above sea level, is the

most active volcano along the CVL (see Fitton, 1980) having erupted seven times (1909, 1922, 1954, 1959, 1982, 1999 and 2000) in the last century (Suh et al., 2003). With the exception of its 1954 eruption, all of its other eruptions have produced destructive earthquakes and lava flows with significant impact to the environment (**Figure 1(a)**). For example, hazards from its 1999 eruption disrupted the socio-economic life and livelihood of the population living on and around its flanks and resulted in a humanitarian crisis which included the evacuation of over 600 people from the coastal village of Bakingili (Ghogomu et al., 1999; Wantim et al., 2018) which was situated along the path of the lava flow field that destroyed forests, agro-allied plantations and road infrastructure. Ash falls from the eruption destroyed crops, polluted potable water sources, and caused major health concerns (Atanga et al., 2009) to the inhabitants living on the western flank. Earthquakes that accompanied the eruption destroyed over 60 houses, displacing approximately 250 people in the city of Buea (Wantim et al., 2018).

Previous work carried out for eruptions resulting from MC mostly centred on its seismicity (Ateba et al., 2009), tectonics (Mathieu, Kervyn & Ernst, 2011), petrology and geochemistry (Fitton et al., 1983; Suh, Luhr, & Njome, 2008). Recently, focus on lava flow studies at MC has shifted towards morphological (Wantim et al., 2011, 2013a) and lava flow hazard assessment (Favalli et al., 2011; Wantim et al., 2013b; Gehl et al., 2013; del Marmol Fontijn et al., 2017). Previous risk awareness and perception studies have mostly been based on household surveys show that risk (volcanic) is perceived differently among local scientists and the local populations (Njome et al., 2010; del Marmol Fontijn et al., 2017). The risk perception study of Njome et al. (2010) was carried out in 2008 and was limited to two rural localities at the flanks of MC, sampling just 70 persons without considering the coping strategies used by the population.

MN (stratovolcano with an elevation of 3470 m), situated ~15 km north of the town of Goma and Lake Kivu and just west of the border with Rwanda (Tedesco et al., 2007), is the second most active volcano in the Virunga Volcanic Province (VVP) after Nyamuragira (Ayonghe & Wantim, 2016) having recently erupted 3 times (1977, 2002 and 2021; **Figure 1(b)**). The volcanic field of MN is surrounded by volcanic fields of Nyamuragira in the north and west, Karisimbi and Mikeno volcanoes in the east, and by Lake Kivu on its southern side (Ross et al., 2014). Its recent eruption on 22 May 2021 that lasted for just a day, produced lava flow that destroyed approximately 1000 homes, killed approximately 32 people, and displaced over 450,000 people (ECHO, 2021; IFRC, 2021; UNHCR, 2021). Other humanitarian disruptions included lack of clean water which triggered a cholera outbreak, scarcity of food, as well as power outage in parts of Goma city. Prior to its 2021 eruption, its 1977 and 2002 eruptions were classified as the only known cases in the world where people were directly killed by lava flows (Wright et al., 2012). Its 2002 eruption which lasted for just one day, produced lava which destroyed 15% of Goma, killed approximately 150 people and displaced 300,000 people (Tedesco et al., 2007; Wright et al., 2012). This volcano

hosts within its crater the world's largest continuously active lava lake (Burgi et al., 2020). The presence of this lake constitutes a major source of hazard that has the potential to cause catastrophic impact to the cities of Goma (Democratic Republic of the Congo (DRC)) and Gisenyi (Rwanda) with about 1.5 million people (Burgi et al., 2020) living at its foot. Such impacts were observed during its recent 2021 eruption and previous eruptions from this volcano.

Previous studies at MN have mostly centred on lava flow mapping (Smets, Wauthier, & d'Oreye, 2010), modelling (Favalli et al., 2009) and understanding of the magma plumbing system (Tedesco et al., 2007; Burgi et al., 2020). Recent studies by Michellier et al. (2020a, 2020b) and Nyandwi et al. (2023) have covered areas of the population's vulnerability, health, communication challenges to volcanic risk and risk perception. Nyandwi et al.'s (2023) study on risk perception was conducted in 2021 and described the spatial differences and factors influencing the individual volcanic risk perception in terms of perceived severity and vulnerability. This is a completely different approach from the approach used in this study, which uses specific eruption scenarios. Nyandwi et al. (2023) limited their study to 7 localities in the city of Goma, whereas a total of 15 localities (with sub-localities) have been covered in this study. Notwithstanding, studies on the population's perception to this risk which is relevant for disaster preparedness and mitigation, are still very rudimentary taking into consideration the population density of Goma.

1.2. Description of the Study Sites

The population of major cities on the flanks of MC (e.g. Buea and Limbe) has drastically increased during the last 10 years. As per the census results of 2005 (BUCREP, 2010), approximately 350,000 people inhabited the major cities, towns and villages around MC. The population in the city of Buea at the time was ~130,000 people (BUCREP, 2010) being the most populous at the flanks of MC (**Figure 2(a)**). This number increased to 300,000 people in the city of Buea alone by 2013 (BUCREP, 2013). The city of Buea (**Figure 2(a)**) which is the headquarters of the South West Region, situated on the SE flank of MC (a stratovolcano) which is the highest mountain in Central Africa (Kamguia, Tadjou, & Ngouanet, 2015), is considered one of the major cities on the slope of this volcano. Population increases in this city began with the creation of the University of Buea in 1993 and other higher institutions of learning that sprung up after its creation. The advent of these higher institutions of learning led to an influx of people from different ethnic groups and increased economic activities. There has also been a major influx of people into Buea in the last four years (since 2016) (Bang & Balgah, 2022) with the advent of the socio-political crisis in the North West (NW) and South West (SW) Regions of Cameroon. The population today is estimated at ~500,000 people. This increase is linked to the influx of internally displaced persons fleeing other parts of the SW and NW Regions of the country which are more affected by the on-going civil strife. This has led to the influx of people who have never experienced any of the eruptions from MC, lack total

awareness and who in the event of such an occurrence will face difficulties to cope with the resultant hazards.

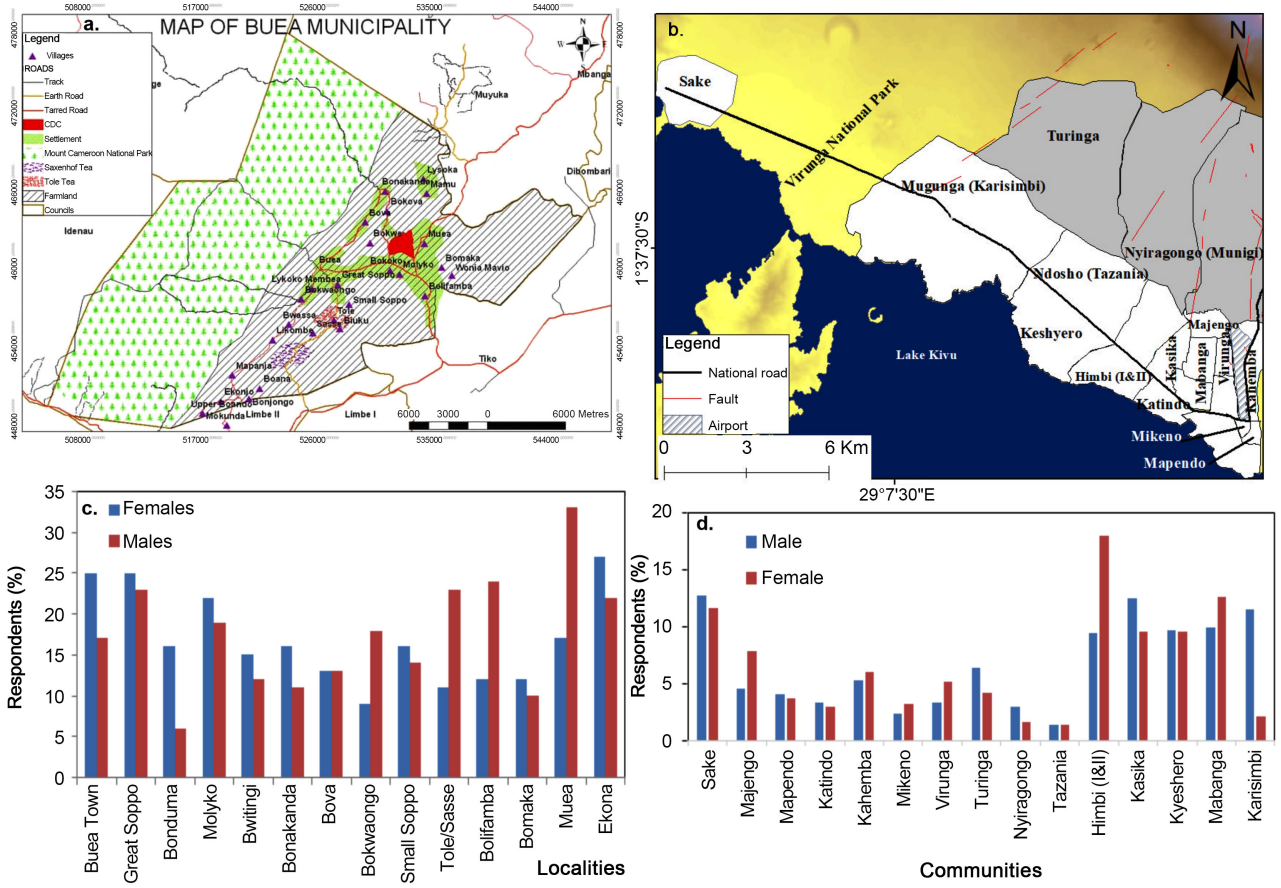

Figure 2. Illustrations showing (a) map of Buea Municipality with inset maps of Cameroon, South West and Fako Division obtained from the Buea Council showing some of the sampled localities; (b) map of Goma showing some of the sampled neigbourhoods; (c) & (d) histograms showing the studied localities and gender of the sampled population in Buea and Goma, respectively.

The city of Goma (**Figure 2(b)**) and its surrounding villages are among the world's most densely populated regions strongly affected by volcanic hazards (Balagizi et al., 2018). Goma is situated in the Eastern part of DRC bordering Rwanda and considered as the capital city of Northern Kivu Province in DRC. The population of Goma is ~1,000,000 inhabitants, however when added to that of neighbouring Gisenyi (Rwanda), it gives a total of ~1.5 million inhabitants (Nyandwi et al., 2023) who continue to live with the threat of new lava flows and other eruptive hazards from MN. Goma is situated 20 km away from MN and faces multiple threats: active volcanoes, a potential gas explosion from Lake Kivu (Ayonghe & Wantim, 2016), ethnic conflicts and political tensions. The deep waters of lake Kivu contain enormous amounts of dissolved CO_2 (250 km^3 STP) and CH_4 (60 km^3 STP). The release of just a fraction of these gases will have catastrophic consequences on the inhabitants. Apart from the destructive lava flows that result from MN's eruptions, the population is constantly exposed to poisonous volcanic carbon dioxide gas (*mazukus*), which kills tens of people

yearly in Goma and has been classified as the most lethal volcanic hazard for the area in terms of human losses (Ayonghe & Wantim, 2016). Situated at the flanks of both volcanoes (MC and MN) are important infrastructures of social, economic and administrative importance which are all exposed to the resultant volcanic hazards and require protection.

2. Methods

This study made use of the transdisciplinary research approach which is a participatory approach involving both scientists, major stakeholders and members of the local communities. From its conception and design phase, focus group discussion sessions were held with scientific (environmental and earth scientists, medical personnel's and sociologists) and non-scientific (mayors, media, traditional rulers, religious, civil protection, local community members) stakeholders in the community. From these discussions, the research questions and objectives used in this study were developed. At the flanks of MC and MN, the participants for the study were selected from a total of 14 and 15 communities within Buea municipality and Goma city respectively. Engaging with the local population living at the flanks of these volcanoes to understand their knowledge, though mandatory in the management and preparedness of their resultant hazards, has often been neglected.

2.1. Focus Group Discussions

The study was initiated with co-design workshops held in the cities of Buea (35 persons) and Goma (35 persons) in 2017 with key stakeholders from the scientific and non-scientific sectors that included: regional governors, city and municipal mayors, media, health personnel's, civil defence, red cross, urban planning, scientific research (University of Buea and Goma Volcano Observatory), civil society (traditional rulers, clergy and quarter heads). The purpose of these focus group discussions was to develop the research objectives of the study taking into consideration the communities perspective. Once the objectives were clearly defined, the discussion proceeded by examining the perception of the participants on the causes of eruptions from these volcanoes and the coping strategies used by the population to reduce the impact.

2.2. Data Collection and Analysis

2.2.1. Participants and Setting of the Study

The participants for this study were selected from 14 communities within Buea municipality situated ~12 km from MC and 15 communities (hosting several sub localities within Karisimbi community: Ndosho, Kisasu, Lusaka, Ngongo, Minova, Renga and Orphelinat; with Himbi I and II merged) within the city of Goma situated ~20 km from MN (**Figure 2(c)**, **Figure 2(d)**). The cities of Buea and Goma are a blend of urban, semi urban, and rural settings. For this reason, the selected localities in both cities were representative of all the settings. Data collection in both cities was carried out between 2017 and 2018. The statistics for

the chosen localities and gender for the participants who participated in this study are represented on **Figure 2(c)**, **Figure 2(d)**.

A total of 500 and 1000 questionnaires were administered to participants within the 14 and 15 communities of Buea and Goma, respectively, in the first phase of data collection (the second phase was based on health impacts, discussed in another manuscript under development). The size of the sampled population was not considered a major issue in this study because the results are not intended to be generalized across the entire population of these cities, but rather to generate a basic understanding of the risk perception and coping strategies for the communities within Buea and Goma cities. A condition to qualify to participate in the survey was mainly that the participant must have lived within Buea and Goma cities during any one of the different volcanic events (i.e. 1959, 1982, 1999 and 2000 MC; and 1977 and 2002 for MN) considered in this study. While in the field, each questionnaire was filled out by members of the research team through semi-structural interviews with the respondents. The administration of questionnaires was mainly door-to-door to avoid duplication and in order to ensure participants met the above condition hence utilization of the face-to-face interviews and snowball technique (Balso & Lewis, 1997). Gender was also given significant importance in this research. This is because majority of the studies of risk perception have shown that females tended to rate risk higher than males for both natural and anthropogenic disasters (Brown, Largey, & McMullan, 2021). A lack of gender diversity could therefore have an adverse impact on the quality of the analysed results. The participants were not contacted before the contact with research team members hence they did not have any time to prepare for any likely response(s). However, the localities targeted for questionnaire administration were purposively chosen to reflect the communities of the stakeholders (especially the traditional leaders and quarter heads) who participated during the design phase. The field interviewers were members of the research team from both Buea and Goma who have significant experience in research, thus required no training prior to the exercise. In this way, their responses to some of the questions may reflect their line of action in the wake of a future disaster given that some disasters may occur without any lengthy warning period.

Of the total number of questionnaires administered, 481 (out of this number 248 (52%) were males and 233 (48%) females; **Figure 2(c)**) were retained in Buea and 973 (out of this number 545 (56%) were males and 428 (44%) females; **Figure 2(d)**) for Goma. The questionnaires that were discarded were due to missing data. The participants for this study were divided into three age groups as follows: 1) 18 - 30 years (53.7% female and 46.3% male); 2) 30 - 45 years (44.6% female and 55.4% male); and 3) above 45 years (51.4% female and 48.6% male). The aim was to derive knowledge on how risk is perceived across different age strata of society so as to better target future efforts towards awareness raising and capacity building as well as coping mechanisms.

2.2.2. Survey Material

The questionnaire used in this study was a simple one composed of five questions that were developed by the researchers intended to directly appraise risk perception and coping strategies of participants living on the flanks of MC and MN. The same questions were posed in both cities, to be able to get a good appraisal of the population's perception and carryout a comparative assessment. The questionnaire focused on the following key issues:

1) *Risk perception from four previous eruptions of MC namely* 1959, 1982, 1999 *and* 2000 *eruptions and two previous eruptions from MN namely* 1977 *and* 2002. The question sought to investigate how participants perceived risks from these eruptions based on a 5-point Likert scale ranging from very low = 1, low = 2, medium = 3, high = 4, very high = 5, to none. Respondents were also able to indicate the response "I don't know".

2) *Effect of these eruptions on participants*. This question (close-ended) sought to appraise the effect that these eruptions had on participants based on an assigned reference: fear/panic, destruction of building/property—heavy, medium, and slight, physical harm and no effect.

3) M*easures that will enable you to cope with future volcanic risk:* This question (close-ended) sought to assess participants coping strategies especially with the idea that the volcano is an active one and may erupt anytime in the future. Four response options were presented namely a) sensitization of population, b) use of traditional/indigenous strategies, c) religious (Christian) strategies, and d) I do not know.

4) *Knowledge of traditional/indigenous strategies to enable participant to cope with the above risks*. This question required a simple yes or no response and a listing of them if the respondent answered "*yes*".

5) *Actions to be taken in the event of a future volcanic eruption or earthquake*. This question was close-ended with the following responses: a) run, b) pray; c) stay calm, d) sensitize, e) tradition, and f) others.

All of the above questions used in this study focused on specific issues related to the objectives of this study, hence the study did not consider other aspects that could pose risk to these communities as a consequence of their daily living in these cities ranging from socio-economic to health including disease prevalence, crime waves and poor transport services. This has been addressed in another study still under development. Question (5) was omitted in the questionnaire of Goma by accident (this was only realized when the data was being processed), thus was not applicable for the communities there.

2.2.3. Data Analysis

The SPSS version 17.0 was used to analyse data collected from the field. The choice options presented in "(1)" and "(2)" above were ranked and used to establish arbitrary indices, which was then used to assess risk perception of participants, the effect of the cited eruptions on humans and the level of damage to property/infrastructure. Most of the data were analysed using basic statistics to

obtain proportion of participants' representation within a selected response choice. More so, the *Chi-square* X^2 test was used to establish whether categories like gender and age group have any significant relationship with risk perception for the studied eruptions.

For MC, a risk perception index was further calculated which is the grade point average methodology where the frequencies of responses are multiplied against their corresponding weight grade point. This method is commonly used to describe and make interpretations of distributional responses when using Likert scale instruments (Clason and Dormody, 1994; Dwivedi and Pandey, 2021). The 5-point Likert scale was used to generate the risk perception index at MC for questions (1) and (2) as summarized in Table 1.

Table 1. Risk Perception Analyses for the 1959, 1982, 1999 & 2000 eruptions of MC.

Variables	Scale (L)	Weight (N)	1959		1982		1999		2000	
			Freq.	Prod. (L*N)	Freq.	Prod. (L*N)	Freq.	Prod. (L*N)	Freq.	Prod. (L*N)
Risk Perception	Very high	5	30	150	60	300	181	905	101	505
	High	4	12	48	26	104	115	460	119	476
	Medium	3	11	33	20	60	47	141	80	240
	Low	2	3	6	9	18	19	38	29	58
	Very low	1	0	0	3	3	15	15	10	10
Total			**56**	**237**	**118**	**485**	**377**	**1559**	**339**	**1289**
Perception Index (Mean)				**4.23**		**4.11**		**4.14**		**3.80**

NB: The same principle on this table was used to address question "(2)" on the effects of persons and property represented on Table 2. To obtain the Risk Perception (mean) the total of product was divided by the total number of response frequency (i.e. risk perception for 1959 = 237/56). The value obtained was then compared with the values of the different weights, since it was weight on a 5-point scale where 5 is very high and 1 is very low, the value of 4.23 was therefore equated to be equivalent to the scale of high; thus, risk perception = high.

3. Results

3.1. Perception of Causes of Eruption

Knowledge on the causes of eruption was assessed during the focus group discussion sessions held in Buea and Goma. There were two schools of thoughts regarding knowledge on the perception of the causes of volcanic eruptions. The first school of thought (the population living at the flanks of MC principally in the city of Buea) cited that eruptions from this volcano are caused by magma and gas ascent. The second school of thought cited the anger of the god of the mountain locally referred to as *"effassa moto"* and the death of a noble (such as a traditional ruler or paramount chief) as the main triggering factors for eruptions at MC. Eruption products from this volcano such as lava, was believed to be fire spat by the gods when they get angry. Pouring of libations, offering of animal sacrifices and incantations were cited as coping strategies to appease the gods and put an end to eruptions.

The population (first school of thought) in Goma cited seismic and tectonic activities in the area as being responsible for the onset of eruptions from MN. The second school of thought were of the opinion that MN eruptions occur because of the following: anger of the ancestors/gods and satanic spirits/demons, punishment from God Almighty, tribal conflicts, presence of minerals and other substances believed to be deposited by foreigners and disrespect of traditional customs such as the failure of offering sacrifices to the gods. Others believed that the volcanic hazards that accompany eruptions from MN were: *mazukus* (CO_2 concentration) perceived as ancestral urine/rites; evil spirits that bring death; toxic substances deposited by foreigners to hide precious resources and tribal boundaries. Volcanic ash was attributed to be the product that results from the quarrel between two traditional chiefs. The impact of high fluorine that causes brown stains in teeth was regarded by the community in Sake as their tribal identity. The population at the flanks of both volcanoes viewed their eruptions as near-death experiences marred with severe health impacts while others saw it as an exciting experience and a blessing.

3.2. Perception of Risk

Risk perception was assessed based on a ranking scale from very high to very low and a last option of "do not know". For all four eruptions at MC, 45% of the sampled participants perceived that they posed very high risk. Participants who thought none of these eruptions posed any risk were less than 5% on the average. Taking the 1977 and 2002 eruptions for MN, 35% of the respondents perceived that they posed very high risk. Just 6% of the population thought that none of these eruptions posed any risk (low to none). Over 25% were ignorant (did not know) about the risk posed. In the case of instances where participants demonstrated ignorance of risk perception (i.e. "do not know"), it was observed that the age group 18-30 years represented the greatest proportion for eruptions from both volcanoes. None of the participants of this age group experienced the 1959, 1982 (MC) and 1977 (MN) eruptions from these volcanoes (even though they had experienced the 1999/2000 eruptions or both at MC; and the 2002 eruption of MN), thus their ignorance (Figure 3).

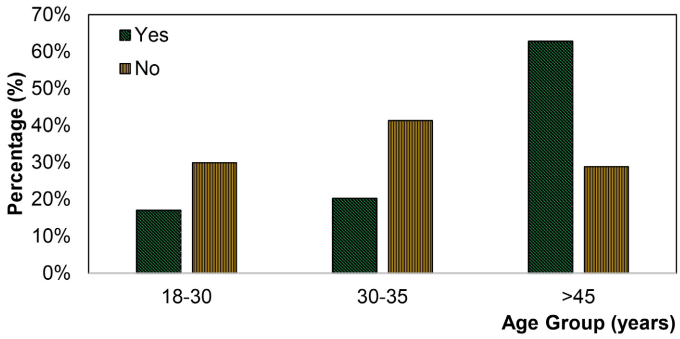

Figure 3. Histogram showing the perception of the various age groups in Goma in relation to the 1977 and 2002 eruptions.

The perception of risk also varied from community to community at the flanks of MN with the most knowledgeable communities being Sake, Majengo and Mapendo being the most affected communities.

Based on a ranking of the response options given for questions related to risk perception, effect of eruption on persons and effect of eruptions on buildings and other infrastructure, a risk perception index was developed for MC (Table 2). Participants perceived risk from the 1959, 1982, and 1999 eruption as high with a perception index slightly above 4.00 while for the 2000 eruption, the perception index was 3.80 representing medium. In terms of direct effect on persons, over 90% of participants in all 14 communities attest that they suffered from fear/panic with an index slightly above 2.80. The effect on buildings/infrastructure was also described as slight for 1982, 1999, 2000 eruptions and medium for 1959 (Table 2).

Table 2. An assessment of risk perception by participants at MC based on an arbitrary perception index.

Aspect of Risk		Perception Index							
		Mount Cameroon							
		1959		1982		1999		2000	
		Value	Rank	Value	Rank	Value	Rank	Value	Rank
1.	Risk Perception	4.23	High	4.11	High	4.14	High	3.80	Med
2.	Effect on persons	2.80	Medium	2.86	Medium	2.87	Medium	2.84	Medium
3.	Effect on Buildings	2.27	Medium	1.86	Slight	1.75	Slight	1.56	Slight

A *chi-square* X^2 test was calculated for gender and age group variables on risk perception for the four eruptions of MC. For gender, the following results were obtained: 1959: $X^2 = 5.031$ and $\alpha = 0.412$; 1982: $X^2 = 5.282$ and $\alpha = 0.508$; 1999: $X^2 = 10.257$ and $\alpha = 0.114$; and for 2000 $X^2 = 16.196$ and $\alpha = 0.013$. Hence risk perception showed a significant difference across gender only for the 2000 eruption. For age group, the following results were obtained: for 1959 $X^2 = 21.862$ and $\alpha = 0.016$; for 1982 $X^2 = 31.252$ and $\alpha = 0.002$; for 1999 $X^2 = 28.430$ and $\alpha = 0.005$; and for 2000 $X^2 = 10.154$ and $\alpha = 0.602$. Hence, risk perception showed a significant difference across age group for the 1959, 1982, and 1999 (with α-values in all three cases less than 0.05) but not significant for the 2000 eruption (with α-values greater than 0.05). Overall, the female gender perceived risk to be *very high* from these eruptions compared to the male gender.

At Goma, respondents perceived risk from the 1977 eruption as *low* (29%) due to the fact that a good number of them (43%) did not experience it. While risk from the 2002 MN eruption was perceived as *high* to *very high* as attested by 80% of the respondents. In terms of its effects on persons, the dominant effect was fear/panic as cited by 19% and 31% of the respondents for the 1977 and

2002 eruptions, respectively. There was significant infrastructural damage cited for the 2002 eruption (56%) in comparison to the 1977 eruption (38%). A *chi-square* X^2 test was further made for gender and age group variables on risk perception of the two eruptions of MN. A negatively weak correlation/relationship existed between age group and risk perception, r = −0.238; p = 000. This is also in confirmation to the fact that $X^2 > 19.85$ where the null hypothesis was rejected and the alternative accepted. In essence, as the age increased, the risk perception reduced and as the age reduced the risk perception increased. This increase or decrease is significant but weak. Taking gender, there was an insignificantly positive very weak correlation/relationship that existed between gender and risk perception, r = 0.022; p = 0.628. This is also in confirmation to the fact that $X^2 <$ 0.234 where the null hypothesis was accepted and alternative rejected. This means that, the way male and female perceive risk in communities at the flanks of MN are almost the same.

3.3. Coping Strategies

Sensitization (i.e. physical actions taken to raise awareness) was cited as the main coping strategy for 10 out of the 14 communities at the flanks of MC and 11 out of the 15 communities in Goma (**Figure 4(a)**, **Figure 4(b)**). At the flanks of MC, three communities showed a relatively slightly higher preference for traditional/indigenous strategies (19% - 29%) and religious strategies (41% - 52%), namely Bonakanda, Bova and Bokwaongo. In comparison at Goma, there was a significantly higher preference for religious strategies (60% - 71%) in Mikeno and Mapendo, respectively. Affiliation to traditional/indigenous strategies (0% - 15%) was the least cited in all the communities with no one even mentioning them in Mapendo, Katindo, Kahemba and Tazania. However, communities at both MC and MN showed a lower preference to the use of traditional strategies to cope with volcanic risk as over 80% of the participants were not aware if any of such strategies existed.

Just 16% attested that they were aware of such coping strategies. The communities at the flanks of MC that were aware of traditional coping strategies cited offering of animal sacrifices, pouring of libation using local liquor and whisky and chanting of incantations as the strategies used to stop eruptions and prevent hazardous phenomenon like lava from getting to settlement areas. Strikingly, at the flanks of both MC and MN, the communities where participants showed a lower preference for sensitization coincided with a higher preference for religious and/or traditional/indigenous strategies. In terms of lack of knowledge on any coping strategies, the highest proportion (39%) among participants was observed in the Katindo community at the flanks of MN (**Figure 4(a)**, **Figure 4(b)**).

The overall result of participants' preference for the options to cope with future volcanic risks from MC and MN based on age groups is presented on **Figure 5(a)**, **Figure 5(b)**. Participants of all the three age groups at the flanks of MC and MN, showed a high preference for the three given coping strategies in de-

scending order as follows: sensitization of population, religious strategies, and use of indigenous strategies. For sensitization of the population, however, while there was a decrease in percent representations in those who preferred this coping strategy with increasing age for communities at the flanks of MC, with the age group 18 - 30 years showing highest preference and age group > 45 years showing least; the age group 31 - 45 years showed the highest preference for population sensitization in communities at the flanks of MN (Figure 5(b)). This trend was reversed with respect to traditional/indigenous strategies in communities at the flanks of both MC and MN whereby the age group of >45 years showed the highest preference with 9.6 and 12.1% representation, respectively. All the three age groups (at MC and MN) showed almost equal preference for religious strategies with percent representation ranging from 25% (for age group 14 - 30 years) to 33% (>45 years). The proportion of participants who lacked knowledge about coping strategies were more in the age group of >45 years in communities at the flanks of MC and least in the 18 - 30 years. However, this trend was reversed in communities at the flanks of MN where the least knowledgeable where those in the 18 - 30 years age group (Figure 5(b)).

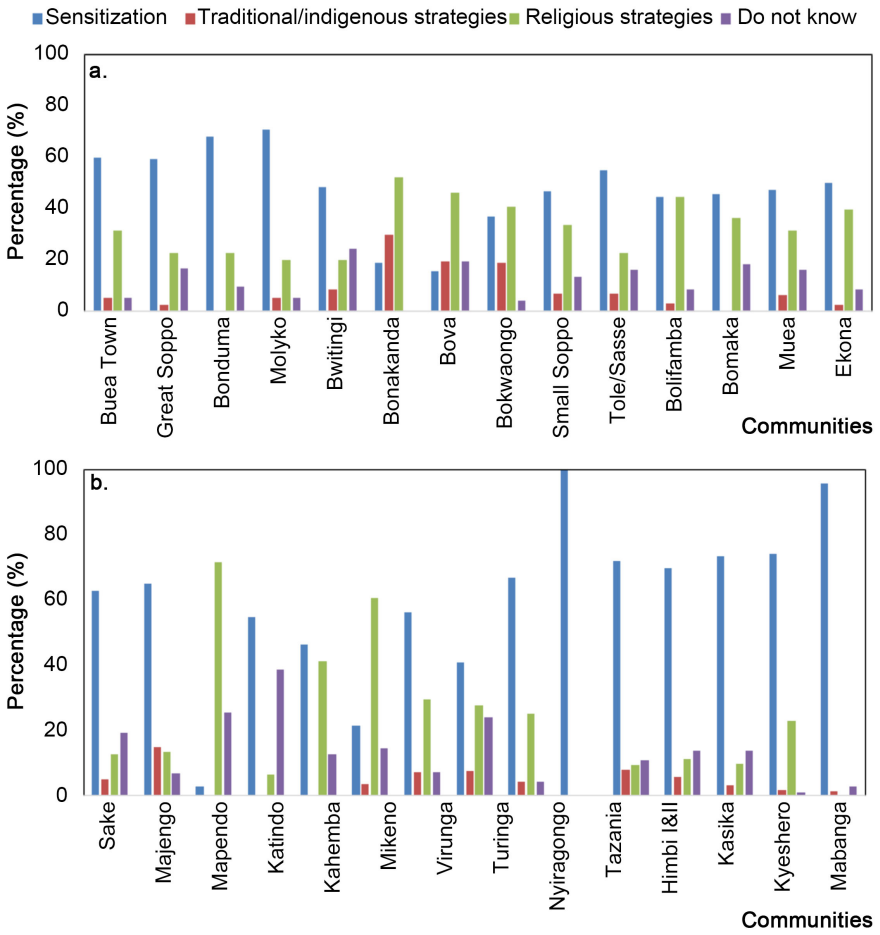

Figure 4. Histograms showing the statistics of coping measures chosen by the different communities in (a) Buea and (b) Goma respectively.

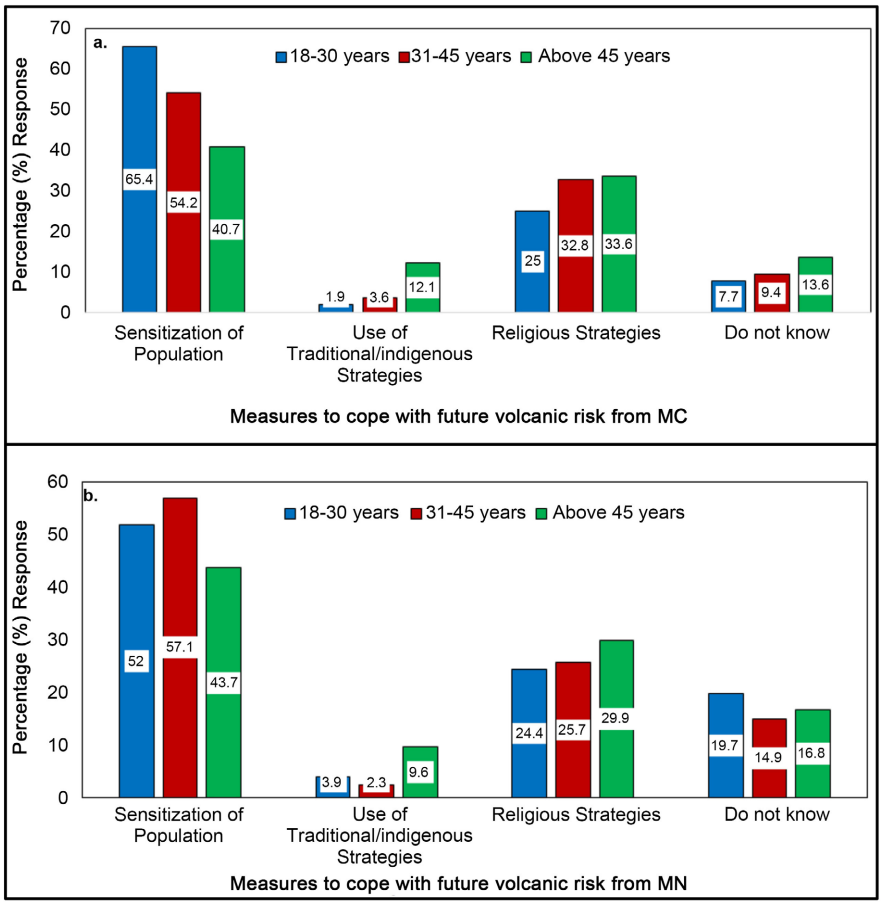

Figure 5. Histograms showing the statistics of measures to cope with eruptions from MC and MN in relation to age group in (a) Buea and (b) Goma respectively.

An analysis of preference for coping strategies based on gender (Figure 6) showed that males showed higher preference for sensitization and traditional/indigenous strategies than females at the flanks of both volcanoes, while at the flanks of MC females (44%) showed a significant higher preference for religious strategies than males (21.6%). The proportion of participants who lacked knowledge about coping strategies was significantly higher in the female participants (25.2%) at the flanks of MN relative to the male (9.7%).

A further assessment of participants' future preference for coping strategies not based on either age or gender at MC (Figure 7(a)) showed in decreasing order of percent representation as follows: sensitization of the population (49.06%), religious strategies (32.49%) and traditional/indigenous strategies (7.13%). At MN the proposed future strategies taking gender into consideration followed this sequence: Male: traditional/indigenous strategies (62%), sensitization of the population (24%) and religious strategies (14%). The females on the other hand prioritized religious strategies (44.1%) first, followed by sensitization of the population (40%) with indigenous strategies (15.9%) being the least of them (Figure 7(b)). The significant percentage proposed by the male at MN for traditional strategies could be due to the fact that they feel betrayed by the scientific

measures (i.e. the presence of a volcano observatory) which have so far been used that has failed to protect the population from the resultant hazards.

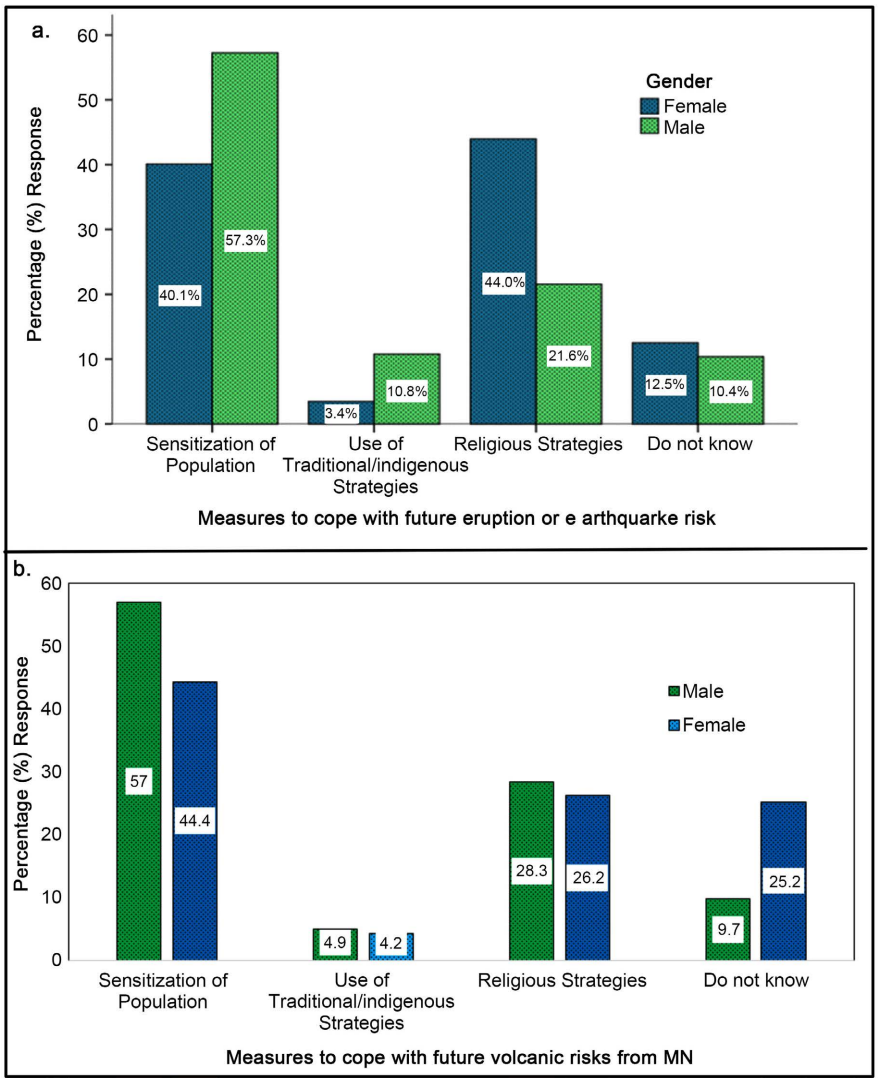

Figure 6. Histograms showing the statistics of measures to cope with eruptions from MC and MN in relation to gender in (a) Buea and (b) Goma respectively.

In terms of actions to take in the event of a future volcanic eruption at MC, 41% of the respondents preferred fleeing away from the resultant hazards, 28% said they will stay put and calm while 22% said they will pray (Figure 7(c)). In analysing the results, it was observed that a majority of those who cited the option to flee where those who lived in Ekona (50.9%) and Bokwaongo (44.4%) which represent communities that were hardest hit by hazards from the 1959 and 1999 eruptions from MC.

A majority of the respondents living in localities like Buea Town, Great Soppo, Molyko and Muea who had little or no impact from the sampled eruptions were those who said they will stay put and calm in the course of a future eruption (Figure 7). Ironically, indigenous rural communities like Bova (40%)

and Bonakanda (45.7%) opted for prayers instead of using traditional strategies to calm the wrath of "*effassa moto*." This could be attributed to the fact that most of the locals who had knowledge of these traditional strategies are no longer alive. The choice of praying instead of running is also due to the fact that these are rural communities characterized with extremely poor road networks which make fleeing almost impossible in the event of an eruption.

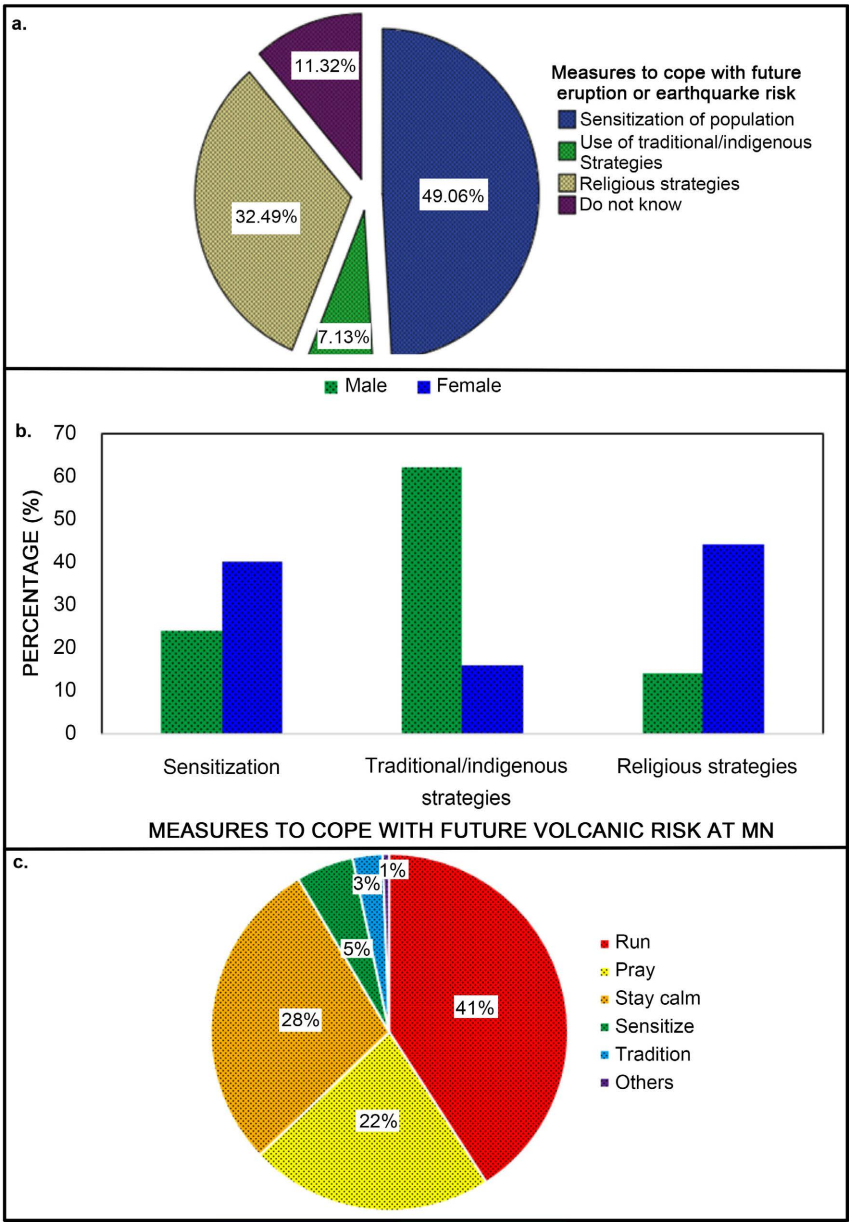

Figure 7. Illustrations showing (a) pie chart with statistics of measures to cope with future eruptions from MC; (b) histogram with gender statistics of measures to cope with future eruptions from MN and; (c) actions to take in the event of a future eruption from MC.

4. Discussion

The population living at the flanks of MC and MN both believe that even though

eruptions are natural processes linked to volcanic and/or tectonic movements, they also have traditional connotations as cited under "causes of eruption" with the principal one being that eruptions occur when the "gods" of these mountains get angry or nobles die or quarrel. The myths/traditional beliefs surrounding the cause of eruptions from these African volcanoes are not restricted to these volcanoes but are present in areas with active volcanoes the world over.

Ethnographical studies carried out by Stoffle & Van Vlack (2022) at the San Francisco volcanic field revealed that Native Americans in the vicinities of these volcanoes see and use these volcanoes as spiritual sights where healing ceremonies are carried out, festivities and power acquisitions. This practice is similar to what happens at the flanks of MC where the indigenous population carry out regular sacrifices to appease "*effassa moto*" and at times see scenarios of eruptions as blessings and periods of festivities and celebration (Mosuka, 2020). The Bakweri indigenes at the flanks of MC believe they have a special bond with "effassa moto" and, because of this great bond, they believed that it was the rituals that were performed by one of the coastal chiefs during the 1999 eruption of MC that stopped the lava from entering into the ocean. Such beliefs are not restricted to African communities, as the indigenous communities on Tanna Island in Vanuatu also see Mount Yasur as their ancestor and they view an eruption from this volcano as an expression of anger by their ancestor (Mount Yasur), thus, just like at MC, they perform rituals to calm the angry spirit of Mount Yasur when it erupts (Niroa & Nakamura, 2022). Similarly, during the 1960 volcanic eruption at Kilauea volcano in Hawaii, where lava destroyed the rural community of Kapoho forcing the evacuation of ~300 residents (Gregg et al., 2008), it subsequently resulted to the performance of rituals and offerings to appease the Hawaiian volcano goddess, "*Pele*" (Lachman & Bonk, 1960). Obtaining information about indigenous belief of communities exposed to volcanic eruptions is therefore a key disaster risk reduction (DRR) factor (Pardo et al., 2015).

Based on our findings on the indigenous perception of the cause and associated risk from these volcanoes, the indigenes at the flanks of MC in particular firmly believe that they know how to communicate with the "god" of the mountain. They are of the opinion that hazards from this volcano (e.g. lava flow) can never get to the settlement of an indigene (Mosuka, 2020). This belief is in line with studies carried out by Jóhannesdóttir & Gísladóttir (2010) in Southern Iceland. In their context locals, due to their cultural background, believed they would be safe from hazards resulting from Mount Katla as their forefathers were. Such beliefs can significantly hinder response efforts during a volcanic crisis as was observed during the 1999 eruption of MC where some indigenes of Bakingili village which was under threat from lava flow inundation resisted evacuation (Wantim et al., 2018). However, the indigenous population living at the flanks of both MC and MN are significantly small in number when compared to the overall population. Also, those still deeply-rooted in traditional beliefs make up just about 1% of the total indigenous population (Njome et al., 2010). This is significantly different with the communities at Tanna Island where the dominant

population are indigenes who are deeply rooted in the belief of the spirit of Mount Yasur. They firmly believe that they can communicate with "it" and successfully cope with the impact of its eruptions. Thus, they have rejected externally based formulated science-based DRR plans (Niroa & Nakamura, 2022). Both MC and MN have volcano observatories installed to monitor activities from these active volcanoes. However, similar to most African volcanoes, eruptions from these volcanoes still take the population by surprise because of the lack of the release of periodic messages on the state of these volcanoes and effective monitoring as cited by Boudoire et al. (2022). The lack of timely scientific information as was observed during the May 2021 MN eruption (Boudoire et al., 2022) is fostering such beliefs, as 62% of the male in communities at the flanks of MN opted for traditional/indigenous strategies to cope with future hazards from this volcano.

Participants in both Buea and Goma are aware of the fact that they live in a tectonically active area that poses great risk as a result of volcanic eruptions and its associated hazards. Participants in the age group above 30 years perceive the risk as *high* to *very high* unlike the age group 18 - 30 years at the flanks of both volcanoes who, in most instance, were ignorant (did not know) of the risk posed by these eruptions. This corroborates with Blong (1984) who showed that middle-aged people usually have a more accurate perception of risk than younger people regardless of their gender. The population in the older age group, may have families and property and thus stand to lose something in the wake of disasters from MC and MN. They would therefore, seem to perceive risk from these volcanoes at a higher level than the 18 - 30 years age group where a great majority are still dependents. Thus, the older people are more worried about safety of property and family than younger people. Contrarily, a similar study assessed volcanic risk perception of young people living in urban areas close to Mount Vesuvius (Carlino et al., 2008) and revealed that, despite 60 years of quiescence at Vesuvius, the interviewed students living in the Red Zone area had relatively appropriate volcanic risk perception. This was attributed to the presence of volcanic risk education programmes embedded in the school curriculum of high school students, which is non-existent in the curricular of schools at the flanks of MC and MN, despite the more active nature of their respective volcanoes.

The level to which participants perceive risk from the four eruptions at the flanks of MC and two eruptions at the flanks of MN represents the nature of activity associated with each event as well as damage that accompanied the events. Among the four eruptions at MC, 1959 and 1999 are the two with eruptions where lava was issued at mean effusion rates of ~18 and 40 $m^3 \cdot s^{-1}$ respectively, producing extensive lava flows on the surface destroying farmland (Suh et al., 2003, 2010; Wantim et al., 2018). Among the two eruptions at MN, the population was more knowledgeable about the 2002 eruption in spite of the fact that both eruptions caused significant damage, where hazards such as lava flows directly caused death (Ayonghe & Wantim, 2016). The significantly low knowledge of the 1977 eruption is likely due to the fact that most of the sampled

population in the age group of 18 - 30 years were not yet born at the time of this eruption. Secondly, at the time of the 1977 eruption, the city of Goma was just a small town hosting a population of just 50,000 people unlike in 2002, where the population had significantly increased to 500,000 people (Tedesco et al., 2007). A majority of the respondents at Goma had witnessed the 2002 eruption. Thus, their risk perception of this eruption was significantly high due to the eye witness observation of its lava flows and ensuing fire outbreak that destroyed one-quarter of the city of Goma. Thus, the findings put forward by Njome et al. (2010) in their risk perception study in rural communities at the flanks of MC that people's perception of risk is linked to manifestation of its hazards holds true for communities in this study. This is because the communities most knowledgeable about volcanic risk were those that had actually experienced direct manifestations of the hazards from these eruptions. For example, the 1999 eruption resulted to damage to buildings in Bokwaongo at MC. Additionally, Sake, Majengo and Mapendo were among the most affected communities from the 2002 MN lava flow. This is also in line with risk perception studies carried out by Nyandwi et al. (2023) at the flanks of MN which showed a positive relationship between high-risk perception and environmental damages and cues. People tend to perceive natural hazards and risks differently from the standpoint of personal judgement (Martínez-Torvisco et al., 1997). Thus, in this study, although a very high proportion of participants perceive risk from MC as high, a relatively small proportion thinks the contrary or is still ignorant ("do not know") about it. Given the position of these communities on the flanks of these volcanoes, it is obvious that the mountain represents a natural hazard of high risk. Taking MC for example, it is an unusually steep-sided lava-dominated volcano characterized with a flat summit plateau, a sharp break in-slope, a rift zone defined by a narrow linear cluster of eruptive vents along its upper flank, a deep valley in the northern flank and topographic steps at its base (Mathieu et al., 2011). The population is living on the topographic steps at its base. Thus, such results show that increase awareness is necessary for all communities in the area.

A significant difference was observed in the way the different gender perceived risk at the flanks of MC in relation to MN. At MC, the female gender perceived the risk from the different eruptions at MC to be more severe than the male gender, while the severity of MN eruptions was perceived similarly by both genders. The disparity observed at MC could be attributed to the fact that women are not household heads, are financially limited, can't take major decisions (as was observed during the 1999 eruption; Wantim et al., 2018). Thus, in the event of a volcanic event, they will suffer more from its consequences, as was the case in 1999. Secondly, as observed by Cuesta et al. (2022), women get more worried about natural hazards than men, especially when family members are concerned since they are the caretakers. They are most often expected to mobilize family members before thinking of their own safety. The perfect agreement of risk severity from both genders at the flanks of MN could be attributed to the fact that hazards from MN affect the population almost equally since the conse-

quences from both the 1977 and 2002 eruption significantly affected both sexes. Thus, risk perception in Goma is significantly induced by the fear of the impacts of the resultant volcanic hazards (Nyandwi et al., 2023), which equally affects both genders.

In terms of coping strategies to resultant hazards from eruptions at MC and MN, a majority of the respondents at both volcanoes, opted for sensitization as the best option. This option is quite reasonable based on the fact that both communities are presently facing significant influx of persons fleeing from conflict regions that lack awareness of their new surroundings and its existing hazards. Religious strategies were also highly recommended by the communities at both MC and MN and particularly by the female population. This is in line with studies carried out by Lachman and Bonk (1960), Gregg et al. (2008) and Bentzen (2019) who cited that individuals develop security seeking behaviour, that is, they turn to religion to deal with unbearable and unpredictable life events. Their studies showed that individuals faced with natural catastrophes are more religious than their counterparts with no risk. This was confirmed in this study as individuals in these communities, found comfort and solace in God. Those who opted for traditional coping strategies were mostly found in three localities at the flanks of MC: Bova, Bonakanda and Bokwaongo and at both the flanks of MC and MN were predominantly male. As previously discussed, these are rural communities principally made up of indigenous people who strongly believe in the "god" of the mountain. Thus, they believe that by pouring out libations or using incantations (Mosuka, 2020) they can be saved from the resultant hazards from these eruptions. In terms of gender, a higher proportion of the male gender at both MC and MN preferred sensitization, while at MC the female gender showed a significant preference for religious strategies. This can be explained from the observation that women are more religiously inclined than men.

Even though this study was limited to the perception of risk in localities in the immediate vicinity of the flanks MC and MN which are active African volcanoes; it is worth noting that volcanoes do not only affect communities in their proximity. Volcanoes have been known to generate cascading effects or significant disruptions in large scale areas as was observed during the Eyjafjallajökull eruption (Gomez-Zapata et al., 2021). Such cascading effects have also been observed for eruptions at MC and MN. Even though these results are not intended to be generalized across the entire population of these cities, they however, generate a basic understanding of the risk perception and coping strategies for these communities.

5. Conclusion

From the comparative analysis of risk perception carried out in this study within 14 localities in the city of Buea situated at the flanks of MC, and 15 localities in the city of Goma found at the flanks of MN, the indigenous population at the

flanks of both volcanoes believe that eruptions from these volcanoes are triggered when the gods of these mountains get angry, thus the need of indigenous coping strategies like the pouring of libations to cope with their resultant hazards especially at the flanks of MC. The sampled population in both cities perceived the risk from the identified eruptions (1959, 1982, 1999, 2000 for MC; and 1977 and 2002 for MN) at both volcanoes to be high in relation to their resultant hazards and the damages caused. However, the age group of 18 - 30 years at the flanks of both volcanoes were the most ignorant in terms of the risk posed by these eruptions due to the fact that none of them in this age group experienced the 1959, 1982 (MC) and 1977 (MN) eruptions. Risk perception also varied from locality to locality at the flanks of both volcanoes with the most knowledgeable communities being those most affected by resultant hazards from these eruptions. In terms of gender, the female gender at the flanks of MC perceived risk from these eruptions to be significantly higher than the male gender, unlike at the flanks of MN where risk perception was considered high by both sexes with no significant difference. In terms of coping strategies, localities within Buea and Goma both preferred sensitization as the major strategy, followed by religious strategies (slightly higher preference in Goma) and lastly indigenous strategies which was more pronounced in rural communities within Buea. However, the males in Goma opted more for traditional/indigenous coping strategies as future options. Looking at preference of coping strategies in terms of age group, at the flanks of MC, the age group 18 - 30 years showed highest preference for sensitization with the least being those >45 years preferring more of indigenous strategies. While at the flanks of MN, it was the age group of 31 - 45 years that showed the highest preference for population sensitization. All the three age groups at the flanks of both MC and MN showed an almost equal preference for religious coping strategies. Taking gender, the males at the flanks of both MC and MN showed a higher preference for sensitization and traditional/indigenous strategies than females, while at the flanks of both volcanoes, females showed a significant higher preference for religious strategies than males.

From the findings of this study, age, gender and eye witness accounts play a significant role in the way risk is perceived at the flanks of both volcanoes. For effective preparedness and response from future eruptions from these volcanoes, there is an urgent need to carry out sensitization of the population living at the flanks of these volcanoes who are characterized with a high youthful population with little or no knowledge on volcanic risk and a significant male population determined to turn back to indigenous strategies due to the lack of timely communication from scientists and other complexities that come with disaster communication. This study is however limited in that the results generated are not intended to be generalized across the entire population in these cities, but limited to the sampled communities.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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