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Impact of climate change on natural hazard-induced disasters in Latin America and the Caribbean

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Climate change-related disasters represent nature's response to the severe and cumulative damage generated by human activities. This article aims to examine such impacts by categorizing Latin American and Caribbean countries according to the number and type of natural hazard-induced disasters recorded between 2000 and 2022, and by assessing the correlation between disaster frequency and national greenhouse gas (GHG) emissions. The study adopts a documentary design with a quantitative and correlational approach. Data were obtained from the International Monetary Fund and Climate Watch Data. Analytical techniques include clustering, principal component analysis (PCA), and Pearson's correlation coefficient. The clustering procedure identified five groups of countries, each characterized by distinct patterns in both the type and frequency of disasters. Findings reveal that Mexico, Brazil, and Colombia are the most affected countries. The PCA results highlight two principal dimensions: (1) hydrological events (floods, droughts, storms, and landslides) and (2) thermal phenomena (extreme temperatures and wildfires). Pearson's correlation analysis demonstrates a moderate yet significant positive association between the incidence of climate change-related natural hazard-induced disasters and GHG emissions. This suggests that, although certain countries combine high levels of emissions with a high frequency of disasters, there are also countries with high disaster occurrence that are not among the largest GHG emitters.

KEYWORDS

natural hazard-induced disasters, climate change, Latin America and the Caribbean, GHG emissions, impact

1 Introduction

Climate change is related to variations in long-term weather patterns, which can be of natural origin, influenced by solar activity or large volcanic eruptions. "But since the 19th century, human activities have been the main driver of climate change, mainly due to the burning of fossil fuels such as coal, oil and gas." In particular carbon dioxide and methane (Nadeau et al., 2022). In other words, anthropogenic activities have had a serious and progressive impact on the environment and consequently on human beings. As illustrated in [Figure 1](#), global temperatures have already changed by almost 1.5 degrees Celsius by 2020, and even the actual observations have exceeded the simulated changes.

Global temperature has risen since 1850, and evidence shows that this warming cannot be explained solely by natural factors, but rather by human influence—particularly since the mid-20th century—mainly through greenhouse gas emissions and land-use changes, which constitute the decisive cause of the current climate change (Romanello et al., 2023).

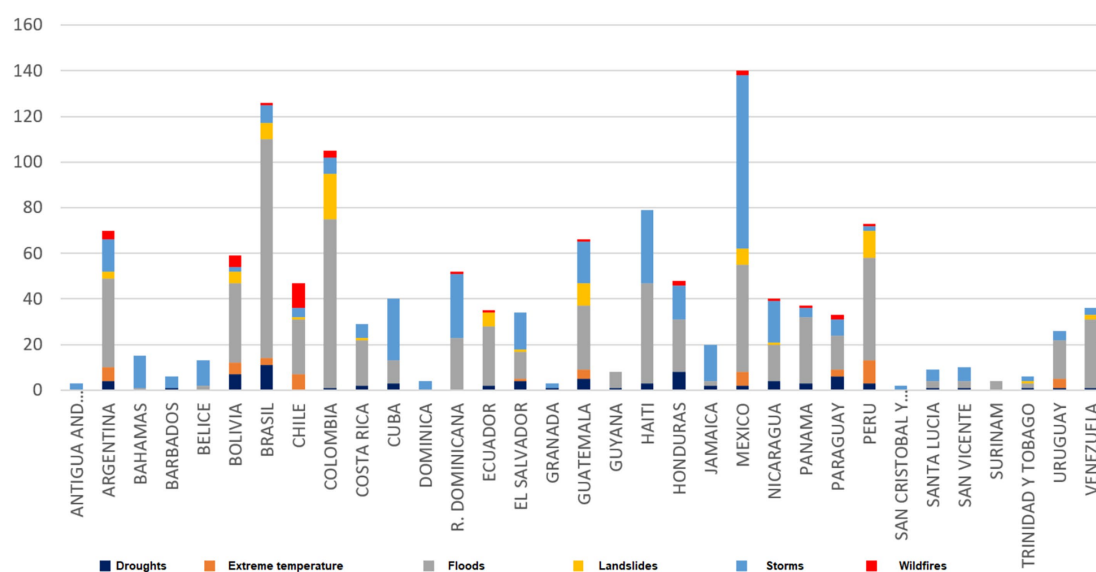


FIGURE 1
Natural hazard-induced disasters caused by climate change (number between 2020–2022).

It is important to emphasize that this situation is neither local nor regional, but global, affecting the entire planet. Moreover, it is not merely projected for the coming years—it is already taking place. Hence, two essential characteristics emerge: first, it is a global problem that threatens the habitability and survival of the entire planet; and second, it is unfolding right now, not in the distant future. These two aspects reflect one of the most alarming consequences of climate change: the intensification of natural hazard-induced disasters (Cappelli et al., 2021).

Consequently, this phenomenon has become the subject of analysis and policy measures by nations worldwide, as its effects are turning against humankind, which has exacerbated them in recent decades. Global warming is currently the issue of greatest concern to nations at all levels, as the planet is already being severely degraded. Human activities—primarily through greenhouse gas emissions—have unequivocally caused global warming (Molder and Calice, 2023). That is to say, many of the disasters the planet is suffering today are the result of climate change and have generated not only sudden deaths, but also costs that represent a heavy and unforeseen burden for nations.

According to data from the Atlas of Mortality and Economic Losses from Weather, Climate and Water Extremes of the World Meteorological Organization (WMO), between 1970 and 2020 there were approximately eleven thousand disasters worldwide, resulting in about two million deaths and more than three and a half trillion U.S. dollars in economic losses. When comparing the periods 2000–2009 and 2010–2019, a slight decrease of 10.49% is observed in the number of reported disasters, as well as a 43.77% reduction in reported deaths, which suggests a degree of preparedness to cope with these events. However, such planning and implementation inevitably involve significant expenditures, as reflected in the 46.60% increase in economic losses (Masson-Delmotte et al., 2021). This underscores the multifaceted impact of this phenomenon on humanity—geological, demographic, and financial.

Climate variability at the global scale is intensifying both the likelihood and severity of extreme weather events. “Rising air and water temperatures lead to sea-level rise, stronger storms, more intense winds, prolonged droughts and wildfires, and heavy precipitation events that result in flooding” (World Meteorological Organization, 2023). These consequences have been progressively worsening, both in frequency and impact. “Climate change and increasingly extreme weather events have triggered a rise in natural hazard-induced disasters over the past 50 years, disproportionately affecting the poorest countries” (Alimonti and Mariani, 2024).

In this context, most countries in Latin America and the Caribbean are either underdeveloped or developing, and several are considered to have limited logistical and financial capacity to respond to natural hazard-induced disasters. As global warming and sea-level rise accelerate, extreme weather events and climate shocks in the region have intensified in both frequency and severity. A recent WMO regional report indicates that over the past 30 years, average temperatures have increased by 0.2 °C per decade—the highest rate on record (United Nations, 2021).

The WMO identifies the most recurrent climate-related disasters as follows: droughts, defined as prolonged periods with precipitation below the mean, leading to reduced water resources and, when severe, resulting in arid conditions and desertification; floods, caused by excessive accumulation of water in a given area; and landslides, which involve uncontrolled mass movements of soil or rock down slopes, often including avalanches, mudslides, and debris flows. Storms—violent atmospheric disturbances accompanied by heavy rain, hail, strong winds, thunder, lightning, and other meteorological phenomena—also rank among the major threats. Additionally, extreme temperatures represent unusual or severe climatic conditions for a given region; thresholds vary geographically, but in many contexts’ temperatures below −10 °C or above 40 °C are considered extreme. Finally, wildfires uncontrolled fires spreading across forest or wildland areas—are characterized by their rapid spread, sudden

changes in direction, and ability to overcome natural and artificial barriers, with severe impacts on vegetation, flora, and fauna.

In their article *Considerations for Climate and Disaster Risk Assessment*, [Mingst et al. \(2022\)](#) examined the fundamental elements required for an integrated evaluation of climate and disaster risk. Their analysis was informed by key international references, including the latest Intergovernmental Panel on Climate Change (IPCC) report, the 2022–2025 Strategic Framework of the United Nations Office for Disaster Risk Reduction, and ISO 14091:2021 guidelines on climate change adaptation, vulnerability, impacts, and risk assessment. The authors emphasize that climate change is “a major driver of the increasing frequency and intensity of non-tectonic natural hazards,” and that its impacts are compounded by land-use and land-cover changes as well as patterns of economic and territorial development. Accordingly, they underscore the need to integrate climate and disaster risk management to better capture the interactions among climatic variations, natural hazards, and their consequences. Such integration entails defining the appropriate scale of analysis, delineating the system under evaluation, identifying relevant hazards and their likelihood of occurrence, and assessing both the system’s vulnerability and its climate sensitivity ([Mingst et al., 2022](#)).

In a regional context, [Menjívar and Guilemes \(2023\)](#), in the chapter *Climate Change and Disaster Incidence in Latin America and the Caribbean* (part of the book *Water, Territorialities, and Dimensions of Analysis*), examined international initiatives to address climate change and analyzed the impacts of climate-related disasters in the region. The chapter presents a timeline of the evolution of the United Nations Framework Convention on Climate Change (UNFCCC) Conferences of the Parties, along with a record of disaster frequency from 1900 to 2010, which increased from 3 to 224 per decade. Furthermore, the National Aeronautics and Space Administration (NASA) has indicated that rising global temperatures and increasing humidity exacerbate drought and flood cycles and contribute to more frequent tropical storms and hurricanes ([Abeldaño Zuñiga et al., 2019](#)).

In this regard, the Sustainable Development Goals (SDGs) aim to support climate change adaptation, particularly in the most vulnerable regions, by integrating disaster risk reduction measures into national policies and strategies, with the objective of limiting the rise in global average temperature to 2 °C above pre-industrial levels. “This highlights the complex interlinkages between climate change, disasters, and sustainable development in the region.” Development in these countries is affected in two ways: disasters drive poverty, and poverty, in turn, heightens vulnerability to disasters ([Menjívar and Guilemes, 2023](#)).

Similarly, [Lee and Sáenz \(2023\)](#), in their article *Disasters and Climate Change: A Paradigm Shift*, sought to provide a broad scientific perspective to prevent distortion of the meaning of two disciplines of vital societal importance: disaster risk management and climate change. Their study emphasizes the historical evolution of both disciplines to organize and standardize knowledge on the key aspects of disaster risk management. They conclude that disasters are not a direct consequence of climate change but rather that climate change should be understood as an underlying factor that amplifies risks. Recognizing and applying this perspective is essential for assuming social responsibility in disaster prevention and management. Attributing disasters solely to climate change diminishes advances in understanding their true implications, since any stance that minimizes

or disregards human responsibility in their occurrence yields negative consequences.

The purpose of this article is to analyze the impact of climate change on disasters in Latin America and the Caribbean from 2000 to 2022, considering both the number and type of disasters per country in order to cluster LAC countries and relate the disaster burden to greenhouse gas emissions. The findings may inform prevention and adaptation strategies to better address natural hazard-induced disasters in the region.

2 Methodology

This research is classified as documentary, based on the search, retrieval, analysis, critique, and interpretation of secondary data recorded in documentary sources, whether printed, audiovisual, or electronic ([Lee and Sáenz, 2023](#)). The data analyzed come from climate-related statistics, particularly concerning natural hazard-induced disasters linked to climate change, obtained from the International Monetary Fund and Climate Watch Data.

The study adopts a quantitative approach, grounded in the measurement of quantifiable characteristics of the phenomena under investigation ([Arias, 2012](#)), as it examines figures on the frequency of disasters—categorized by type—across the countries of Latin America and the Caribbean. It also employs a correlational design, aimed at identifying the relationship or degree of association between two or more concepts, categories, or variables within a specific context ([Pandey and Pandey, 2021](#)). In this case, the design is oriented toward assessing the relationship between the number of disasters and the volume of greenhouse gas emissions in each country.

The main sources of data are the report *Disasters Resulting from Climate Change* ([Hernández Sampieri et al., 2014](#)) and the Total Greenhouse Gas Emissions by Country database ([International Monetary Fund, 2025](#)). Using natural hazard-induced disaster data spanning the period 2000–2022, a clustering analysis was conducted. Clustering is a technique used to group similar data into subsets or clusters, so that elements within a group are more similar to each other than to those in other groups. The purpose is to identify patterns or hidden structures in the data by forming groups based on inherent characteristics that is, grouping elements that are similar to one another and distinct from those in other clusters ([Neumayer, 2000](#)). In this study, clustering was applied to determine groups of Latin American and Caribbean countries with similar profiles in terms of the type and frequency of natural hazard-induced disasters.

In addition, a principal component analysis (PCA) was performed. PCA is a statistical technique that reduces the dimensionality of a dataset while preserving as much of the original variability as possible. It does so by transforming the original variables into a set of new variables, called principal components, which are linear combinations of the originals. These components are ordered such that the first retains the greatest amount of variance, the second the next largest, and so on. This makes PCA useful for simplifying complex datasets, facilitating visualization, and eliminating redundancy among variables, while retaining most of the relevant information ([di Floristella, 2016](#)). In this study, PCA was used to represent the countries on a scatter plot with only two principal components, capturing the greatest variability according to the natural hazard-induced disasters experienced during the study period.

Finally, Pearson's correlation coefficient was applied as a statistical measure to determine the strength and direction of the linear relationship between two quantitative variables. Its value ranges from -1 to $+1$, indicating negative and positive correlations, respectively, and becomes more significant as it approaches either extreme, that is, as it moves further away from zero.

The formula for the coefficient is:

$$r = \frac{N \sum xy - \sum x \sum y}{\sqrt{[N \sum x^2 - (\sum x)^2][N \sum y^2 - (\sum y)^2]}}$$

r : Pearson correlation coefficient, S_{xy} : sum of the products of both variables, S_x : sum of the values of the independent variable, S_y : sum of the values of the dependent variable, S_x^2 : sum of the squared values of the independent variable, S_y^2 : sum of the squared values of the dependent variable.

In this case, the variables to be correlated are the Total Greenhouse Gas and Natural Disaster data, in order to determine their association in terms of Pearson's index. Microsoft Excel and SPSS Statistical Package for the Social Sciences were used for data processing.

3 Results

Figure 1 shows that in the period between 2000 and 2022, the countries that have suffered the most natural hazard-induced disasters are Mexico, Brazil and Colombia. The countries that have suffered the most natural hazard-induced disasters are Mexico, Brazil and Colombia, which have more than one hundred disasters, and the type of disaster that is recurrent and significant in almost all countries is floods and to a lesser extent storms, with Mexico suffering the greatest number of this type of disaster.

The clustering (Figure 2), represented in the dendrogram, shows a first group made up of the countries located to the south-east of the Caribbean Sea: Antigua and Barbuda, Bahamas, Barbados, Belize, Belize, Dominica, Grenada, Guyana, Jamaica, St. Kitts and Nevis, St. Lucia, St. Vincent, Suriname, Trinidad and Tobago. A second group composed mostly of Central and South American countries: Argentina, Bolivia, Haiti, Peru. A third group composed of Brazil and Colombia. A fourth group made up mostly of Central and South American countries, generally with coastlines: Costa Rica, Guatemala, El Salvador, Panama, Honduras, Nicaragua, Dominican Republic, Cuba, Ecuador, Venezuela, Chile, Paraguay and Uruguay. A fifth group is made up of only one North American country, Mexico.

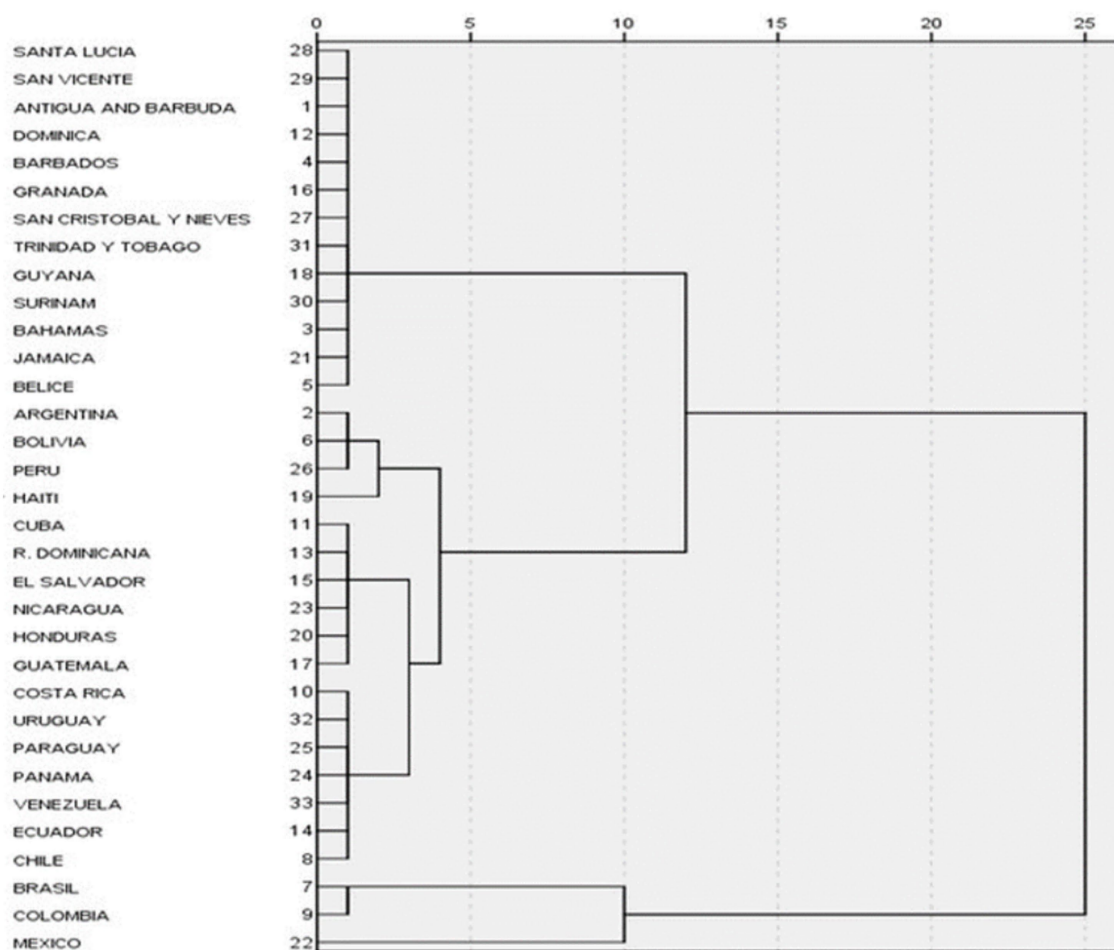


FIGURE 2
Clustering dendrogram.

The map of Latin America and the Caribbean shows geographically the 5 clusters that have been established according to the dendrogram, considering the type and quantity of disasters caused by climate change in the two decades analyzed, as shown in Figure 3.

Table 1 shows the five clusters, considering a comparison of averages for each type of disaster for each group of countries. Considering that the averages are: droughts (2.4), extreme temperatures (1.5), floods (20.5), displacements (2.3), storms (10.9) and fires (1.1). It can be noted that cluster 1 is characterized by very low averages for all types of disasters, with the highest average in this group being storms (5.3), although below the overall average. Cluster 2 is identified by above-average numbers of disasters, droughts (4.3), extreme temperatures (5.3), floods (40.8), displacement (5), storms (12.5), and fires (2.5). Cluster 3 is defined by having a very high number of floods (85), landslides (13.5) and droughts (6) well above the overall average. Cluster 4 is determined by having a disaster volume very close to the overall average, with an average number of floods (21) and storms (11.5). Cluster 5 is differentiated by having the highest number of disasters floods (47) and storms (76), landslides (7), extreme temperatures (6) and forest fires (3).

When performing the principal component analysis (PCA), it can be seen in Table 2 that the first two factors account for almost 63% of

the variance of the data, which is considered acceptable, as it is generally recommended that factors explaining at least 60% of the total variance be retained for interpretation.

The rotated component matrix is analyzed, as it adjusts the factor loadings to simplify the structure, i.e., it redistributes the loadings among the components, allowing each component to more clearly represent certain groups of variables. As a result, interpretations are more straightforward, as each variable is expected to load strongly on a single component, making the relationship between variables and components more evident. As can be seen in Table 3, floods, Droughts, landslides and storms contribute to factor or component 1 with high values, above 0.5. While forest fires and external temperature contribute to factor or component 2 with values above 0.7. Component 1 has therefore been denoted as hydrological events and component 2 as thermal phenomena.

3.1 Rotation method: Varimax with Kaiser normalization

In the scatter graph that shows the two factors mentioned in the principal component analysis, it can be seen in Figure 4, in component

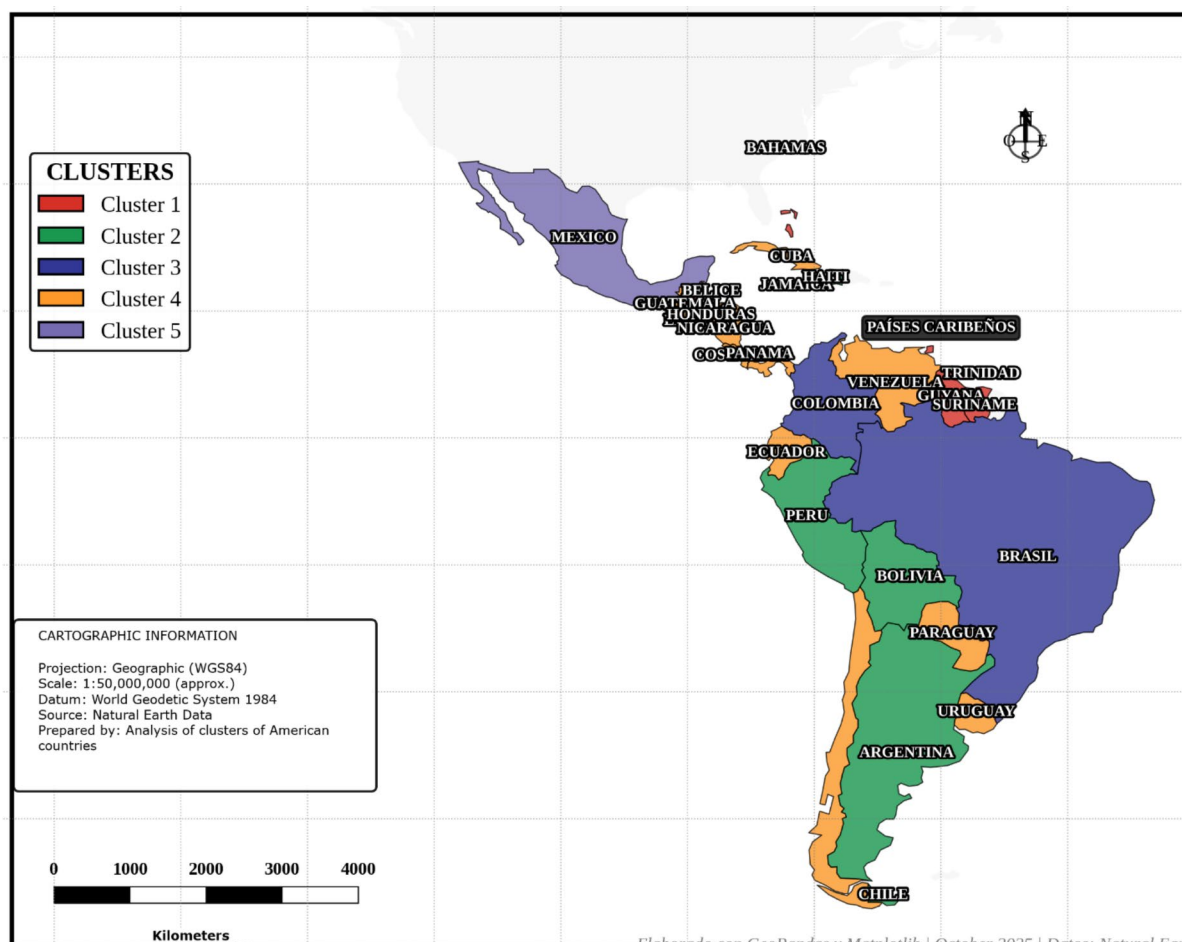


FIGURE 3
Map of LAC according to clustering.

TABLE 1 Comparison of means by cluster.

Ward method	Droughts	Extreme temperature	Floods	Landslides	Storms	Wildfires
1	0.62	0.00	1.85	0.8	5.3846	0.00
2	4.25	4.25	40.75	5.00	12.500	2.50
3	6.00	1.50	85.00	13.50	7.5000	2.00
4	3.00	1.46	21.00	1.69	11.5385	1.54
5	2.00	6.00	47.00	7.00	76.0000	2.00
Total	2.36	1.48	20.52	2.33	10.9394	1.09

TABLE 2 Variance explained by the PCA factors.

Component	Total	% of variance	% cumulative
1	2.687	44.783	44.783
2	1.071	17.858	62.640
3	0.933	15.548	78.188
4	0.762	12.704	90.892
5	0.391	6.522	97.413
6	0.155	2.587	100.000

Method of extraction: principal component analysis.

TABLE 3 Contributions of variables to PCA factors.

	Component 1	Component 2
Floods	0.830	0.397
Droughts	0.672	0.170
Landslides	0.620	0.426
Storms	0.567	−0.188
Fires	−0.21	0.890
Extreme temperatures	0.281	0.798

Extraction method: principal components analysis.

1 called Hydrological events, countries with high values, such as Brazil (7), Mexico (22) Colombia (9), Guatemala (17) and Haiti (19), which implies that in these countries, provisions must be made for events such as floods, droughts, storms and landslides. While in component 2, named as thermal phenomena, Chile (8), Peru (26), Bolivia (6) and Argentina (2), which should rather prevent logistics for phenomena such as extreme temperatures and forest fires, are noted in component 2.

When comparing the volume of disasters (2000–2022) and GHG emissions (2000–2020) measured in MtCO₂e, which means millions of tonnes of CO₂ equivalent (carbon dioxide equivalent –CO₂eq-is the unit used to quantify the amount of GHG emitted in terms of its impact on global warming) in the period since, it can be seen in Figure 5, that in the case of Argentina, Bolivia, Colombia, Guatemala, Haiti, Mexico and Peru there are 60 or more disasters, with GHG emissions of less than 12.8 billion tonnes of CO₂. Only Brazil is the country with the highest number of disasters, with more than 120 disasters and a GHG volume of more than 35 billion tonnes of CO₂.

Pearson's correlation coefficient is 0.67 which, although below 0.8, indicates a moderate positive relationship, and is also significant at the

0.01 level. This implies that there is an association between the number of disasters and the volume of GHG emissions in each country. Although the relationship is not perfect, it is considerable and significant, in other words, there is 99% confidence that there is a real relationship between the two variables (see Table 4).

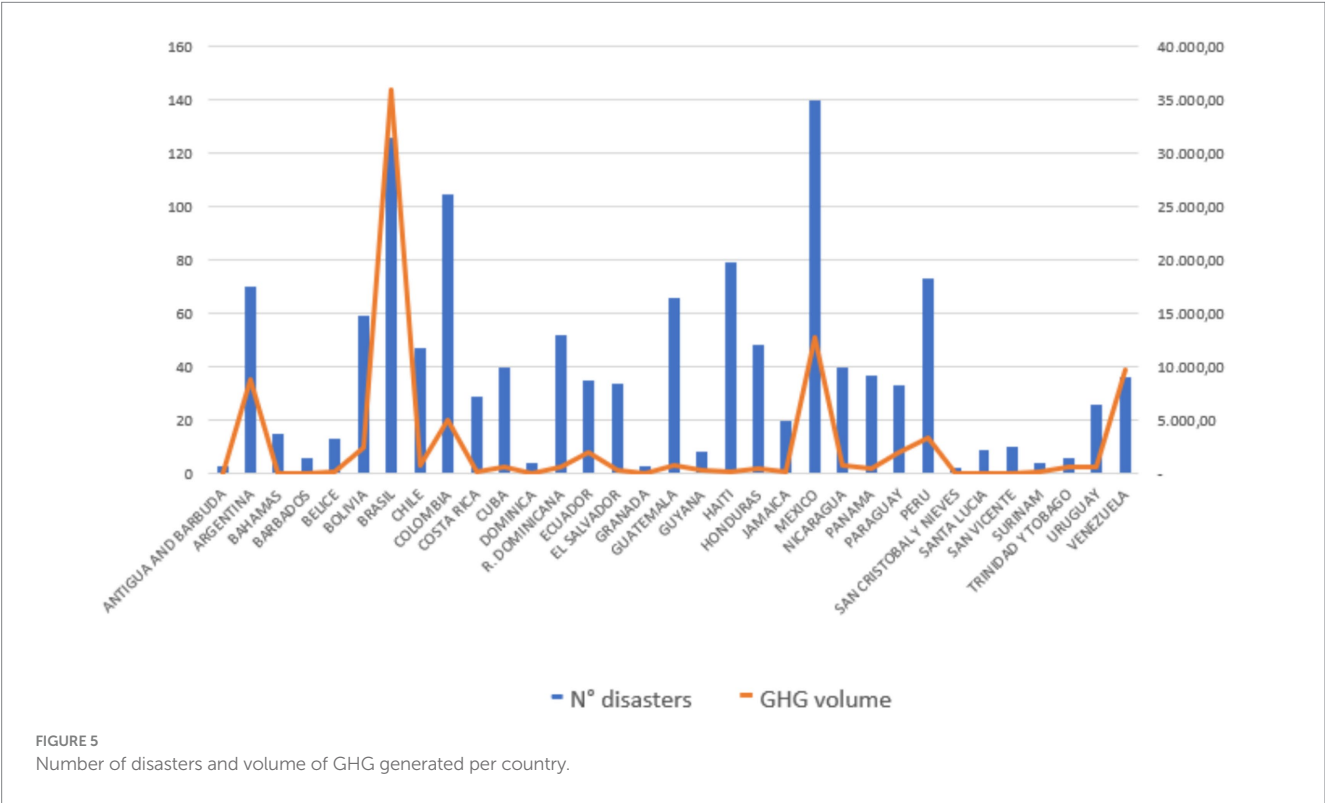
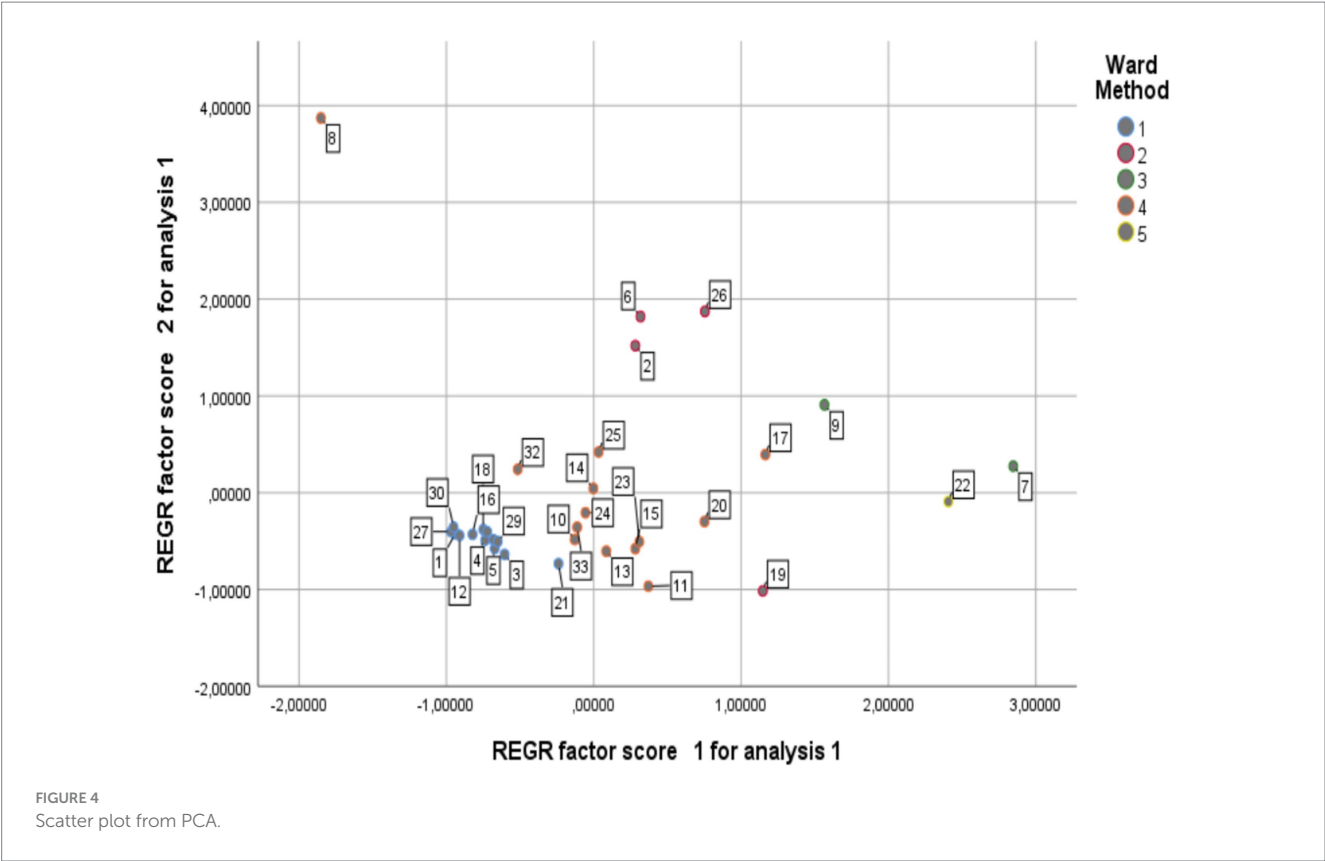
In this case, countries such as Argentina, Brazil, Colombia, Mexico, Peru and Venezuela have high emissions and high volumes of disasters. But there are also other countries in Central America and the Caribbean that have high levels of disasters, although the volume of GHG emissions is low. This is explained by the fact that GHGs migrate from one country to another. These gases, such as carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O), mix rapidly in the atmosphere once they are emitted. Due to air currents, atmospheric circulation patterns and the global nature of the atmosphere, GHGs do not remain confined to a country's borders. For this reason, although some countries may emit more GHGs than others, the impact of climate change is global. Hence, the correlation can be considered moderate to significant positive, underlining the interconnection between climate change and the frequency of extreme events.

In this sense, increased industrial development, growing urbanization and deforestation in a region can lead to both increased GHG emissions and increased vulnerability to natural hazard-induced disasters, not only within its borders, but in the global environment.

This reveals the need to address resilience and environmental sustainability for all nations and in this case for Latin American and Caribbean countries the importance of planning, of being prepared and not relying on the international community, but having good macroeconomic management, which allows for saving resources to cope with these catastrophes. It also means imposing better zoning, so that uncontrolled urban development and agricultural projects do not destroy the mangroves that fix the soil and prevent the rains from bringing landslides. It means having better sewerage and storm water drainage systems, among other vital defences (di Floristella, 2016).

In addition, nations can choose to take out insurance policies against natural hazard-induced disasters, known as CAT bonds, which are generally backed by U.S. Treasury bonds. Although they can be costly, they provide a significant advantage in disaster situations. Table 5 presents a comparison between the study conducted by Abeldaño Zuñiga et al. (2019) and the present research.

When comparing these studies, despite the fact that there is a time difference between them (Abeldaño's study considers studies carried out between 2011 and 2016, while the current one has figures up to 2022, starting in 2000), there are more coincidences than discrepancies in the findings, regarding the patterns that exist in relation to the most recurrent natural hazard-induced disasters in the countries. It is worth noting that the current study is broader, as it is not limited to



the analysis of individual countries, but also identifies groups of countries with similar characteristics, which can be useful for establishing alliances between them, not only for climate change mitigation, but also for dealing with natural disasters, as they suffer from common catastrophes. In other words, in terms of fostering regional and international cooperation in disaster response and

adaptation, sharing resources, policies and technologies, optimising efforts to mitigate the impacts of climate change in similar geographic areas. In pursuit of environmental justice to redress environmental inequalities that affect certain groups more than others, ensuring that environmental policies and decisions do not perpetuate social or economic discrimination.

4 Conclusion

In the period from 2000 to 2022, Mexico, Brazil and Colombia are the countries with the highest number of disasters, exceeding 100 catastrophic events due to climate change, with storms and floods being the most recurrent. While the Caribbean island countries have

had the lowest number of natural hazard-induced disasters, with storms being the most common disaster, as other types of disasters are less common or are mitigated by environmental and geographical conditions, due to their humid tropical climate, which promotes dense vegetation, and their proximity to the sea, which moderates temperatures and reduces the severity of droughts. In addition, its resilient ecosystems such as mangroves and coral reefs act as natural barriers, mitigating the effects of storms and floods.

Cluster 1 is characterized by very low averages for all types of disasters, although with a higher recurrence of storms, and is made up of the countries located to the south-east of the Caribbean Sea: Antigua and Barbuda, Bahamas, Barbados, Belize, Belize, Dominica, Grenada, Guyana, Jamaica, St. Kitts and Nevis, St. Lucia, St. Vincent, Suriname, Trinidad and Tobago. Cluster 2 is identified as having a high number of all types of disasters, with an emphasis on the number of floods and landslides, composed mostly of Central South American countries: Argentina, Bolivia, Peru and Haiti. Cluster 3 is defined as having the highest number of floods, landslides and droughts, made up of Brazil and Colombia. Cluster 4 is defined by floods and storms with figures close to the total average, mostly made up of Central American countries and South American countries, generally with coastline: Costa Rica, Guatemala, El Salvador, Panama, Honduras, Nicaragua, Dominican Republic, Cuba, Ecuador, Venezuela, Chile, Paraguay and Uruguay. Cluster 5 is distinguished by the highest number of storms, floods and extreme temperatures, consisting of only one North American country, Mexico.

TABLE 4 Correlation between the number of disasters and the GHG volume per country.

	Total	GHG
Total Pearson's correlation	1	0.673*
Sig. (bilateral)		0.000
N	33	33
GHG Pearson's correlation	0.673*	1
Sig. (bilateral)	0.00	
N	33	33

*The correlation is significant at the 0.01 level (bilateral).

TABLE 5 Comparative table of disaster studies in LAC.

Current study	Abeldaño Zuñiga et al. (2019, p. 385)	Coincidences and discrepancies
Cluster 1—Countries located south-east of the Caribbean Sea: Antigua and Barbuda, Bahamas, Barbados, Belize, Belize, Dominica, Grenada, Guyana, Jamaica, St. Kitts and Nevis, St. Lucia, St. Vincent, Suriname, Trinidad and Tobago. Low number of disasters. Highest recurrence is storms (5) Cluster 2—Mostly by central South American countries: Argentina, Bolivia, Peru and Haiti. High number of disasters, above average, droughts (4.3), extreme temperatures (5.3), floods (40.8), displacement (5), storms (12.5) and fires (2.5) Cluster 3—Brazil and Colombia. Very high number of floods (85), landslides (13.5) and droughts (6) well above the overall average Cluster 4—Mostly Central American countries and South American countries, generally with coastline: Costa Rica, Guatemala, El Salvador, Panama, Honduras, Nicaragua, Dominican Republic, Cuba, Ecuador, Venezuela, Chile, Paraguay and Uruguay. Number of disasters very close to the total average, with an average of floods (21) and storms (11.5) Cluster 5—Mexico. Storms (76), floods (47) and extreme temperatures (6)	a) Tropical storms, cyclones and hurricanes are frequent in the Caribbean region and on the Mexican Pacific coast b) In the pre-mountain regions, avalanches and landslides are frequent; Chile, Argentina, Ecuador, Colombia c) Floods and storms are frequent in Central America and the Amazon region d) In the north of Mexico and some regions of the trans-Andean region of Peru, Bolivia, Argentina and Chile, droughts affect desert areas	Clusters 1 and 5 match the characteristics of (a), with respect to the Caribbean region and Mexico with a high number of storms Clusters 2 and 3 match the characteristics of (b), with Argentina and Colombia having a high volume of landslides. However, it does not coincide with Ecuador and Chile, where landslides are not the most notable disaster Cluster 4 matches feature (c) in Central American countries with high amounts of floods and storms Cluster 2 also matches characteristic (d) in terms of Argentina, Peru and Bolivia with high numbers of droughts

Abeldaño Zuñiga et al.'s (2019) study points to these findings from the following sources: Aguilar et al., 2011; Corona and Ramírez, 2012; Farfán et al., 2012; Galindo Serrano and Alcántara Ayala, 2015; González, 2013; Inzulza-Contardo and Díaz Parra, 2016; Larios-Tlali et al., 2015; Magaña et al., 2013; Ruiz-Martínez et al., 2013; Sánchez-Núñez et al., 2011; Sandoval-Ayala and Soares-Moraes, 2015.

In the principal component analysis, two factors (63% of the variability of the data) are considered: component 1 hydrological events (floods, droughts, storms and landslides), the most affected countries are Brazil, Mexico, Colombia, Guatemala and Haiti. And component 2 thermal phenomena (extreme temperatures and forest fires) the most affected nations are Chile, Peru, Bolivia and Argentina.

According to Pearson's correlation index, there is a moderate and significant positive association between the number of natural hazard-induced disasters caused by climate change and greenhouse gas emissions per country. This implies that while there are certainly countries with high volumes of GHG emissions and high recurrence of natural hazard-induced disasters, there are also nations that suffer a high number of disasters, although they are not necessarily those that emit the most GHGs. This reveals the imbalance that climate change represents since all nations are victims of the consequences, regardless of their contribution to GHG emissions, as GHGs mix rapidly in the atmosphere once they are emitted and air currents, atmospheric circulation patterns and the global nature of the atmosphere promote their migration and do not remain confined to the borders of one country. It highlights the importance of planning and good macroeconomic management in Latin America and the Caribbean to counteract the impact of natural hazard-induced disasters.

Government policies and measures must go in two directions: On the one hand, to mitigate climate change: Promote renewable energy, with investments in solar, wind, hydroelectric and geothermal energy sources; promote reforestation programs and conservation of natural ecosystems to increase carbon sequestration; develop and promote efficient and sustainable public transport systems, as well as infrastructure for bicycles and electric vehicles; implement regulations and subsidies to regulate emissions and improve energy efficiency in industrial, commercial and residential sectors; offer tax incentives to companies and citizens who adopt sustainable practices and reduce their carbon footprint; and implement education and awareness campaigns on climate change, promoting sustainable practices among the population.

On the other hand, to cope with natural hazard-induced disasters: Develop and implement risk management plans that include assessment, prevention, preparedness and response to natural hazard-induced disasters; establish and improve early warning systems for natural hazard-induced disasters, ensuring that information reaches vulnerable communities; invest in resilient infrastructure that can withstand extreme weather events, such as floods and landslides; and develop and implement disaster risk management plans that include assessment, prevention, preparedness and response to natural hazard-induced disasters.

References

- Abeldañó Zuñiga, R. A., Fabre Platas, D. A., Sánchez, I. O., and Busso, G. (2019). "El cambio climático en la incidencia de desastres en América Latina y El Caribe" in *Agua: Territorialidades y dimensiones de análisis* (Xalapa: Instituto de Investigaciones y Estudios Superiores Económicos y Sociales de la Universidad Veracruzana IIESES-UV).
- Aguilar, V. R. O., Merodio, G. G. G., and Ayala, I. A. (2011). Configuration and temporal dimension of vulnerability: Mestizo spaces and disasters in the Sierra Norte de Puebla. *Investigaciones Geográficas* 75, 61–74.
- Alimonti, G., and Mariani, L. (2024). Is the number of global natural disasters increasing? *Environ. Hazards* 23, 186–202. doi: 10.1080/17477891.2023.2239807
- Arias, F. (2012). *El proyecto de Investigación: Introducción a la investigación científica*. London: Episteme.
- Cappelli, F., Costantini, V., and Consoli, D. (2021). The trap of climate change-induced "natural" disasters and inequality. *Glob. Environ. Chang.* 70:102329. doi: 10.1016/j.gloenvcha.2021.102329
- Corona, N., and Ramírez, M. T. (2012). Técnicas histórico-etnográficas en la reconstrucción y caracterización de tsunamis: el ejemplo del gran tsunami del 22 de junio de 1932, en las costas del Pacífico mexicano. *Revista de Geografía Norte Grande* 53, 107–122.
- di Floristella, A. P. (2016). Dealing with natural disasters: risk society and ASEAN: a new approach to disaster management. *Pac. Rev.* 29, 283–305. doi: 10.1080/09512748.2015.1013498
- Farfán, L. M., Alfaro, E. J., and Cavazos, T. (2012). Characteristics of tropical cyclones making landfall on the pacific coast of Mexico: 1970-2010: 1970-2010. *Atmosfera*, 26,

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found in the article/supplementary material.

Author contributions

MA: Conceptualization, Methodology, Data curation, Investigation, Writing – original draft. PB-E: Project administration, Resources, Funding acquisition, Formal analysis, Writing – original draft. RT: Validation, Supervision, Writing – review & editing.

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Conflict of interest

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163–182. Retrieved from <http://www.journals.unam.mx/index.php/atm/article/view/28075>

Galindo, J. A., and Alcántara, I. (2015). Inestabilidad de laderas e infraestructura vial: Análisis de susceptibilidad en la Sierra Nororiental de Puebla, México. *Investigaciones Geográficas*, 2015, 122–145. <https://doi.org/10.14350/rig.43790>

González, R. C. (2013). Punitive damages and their alternatives in Mexican environmental law. *Mexican Law Review* 6, 45–74. doi: 10.1016/S1870-0578(16)30019-1

Hernández Sampieri, R., Fernández, C., and Baptista, P. (2014). Metodología de la investigación. 5th Edn. Columbus, OH: McGraw-Hill.

International Monetary Fund. (2025). Climate-related disasters frequency. Available online at: https://climatedata.imf.org/datasets/b13b69ee0dde43a99c811f592af4e821_0/about

Inzulza-Contardo, J., and Díaz, I. (2016). Desastres naturales, destrucción creativa y gentrificación: estudio de casos comparados en Sevilla (España), Ciudad de México (México) y Talca (Chile). *Revista de Geografía Norte Grande*, (64), 109–128. doi: 10.4067/S0718-34022016000200008

Larios-Tlali, H., Torres-Benites, E., Quevedo-Nolascol, A., Martínez-Menes, M. R., and Salgado-Tránsito, J. (2015). Riesgo de inundación en la subcuenca del río La Antigua, Veracruz, México. *Tecnología y Ciencias Del Agua* VI, 39–56.

Lee, A. F., and Sáenz, A. V. (2023). Desastres y Cambio Climático: Un cambio de Paradigma. *Rev. Estud. Latinoam. sobre Reducc. Riesgo Desastres* 7:219. doi: 10.55467/reder.v7i1.119

Magaña, V., Clemente, L., and Vázquez, G. (2013). El pronóstico de lluvias intensas para la Ciudad de México. *TIP Revista Especializada En Ciencias Químico-Biológicas* 16, 18–25. doi: 10.1016/S1405-888X(13)72074-6

Masson-Delmotte, V., Zhai, P., Pirani, A., Connors, S. L., Péan, C., Berger, S., et al. (2021). Climate Change 2021: the Physical Science Basis, the Working Group I contribution to the Sixth Assessment Report. Cambridge: Cambridge University Press, 2391.

Menjívar, L. E., and Guilemes, Y. Á. (2023). Consideraciones para la evaluación del riesgo climático y de desastre. *Rev. Iberoam. Ambiente Sustentabilidad* 6:e280. doi: 10.46380/rias.vol6.e280

Mingst, K. A., Karns, M. P., and Lyon, A. J. (2022). The United Nations in the 21st century. New York: Routledge.

Molder, A. L., and Calice, M. N. (2023). What do extreme weather events say about climate change? Comparing politicization and climate policy in US wildfire and hurricane news coverage. *Environ. Commun.* 17, 370–385. doi: 10.1080/17524032.2023.2190495

Nadeau, K. C., Agache, I., Jutel, M., Annesi Maesano, I., Akdis, M., Sampath, V., et al. (2022). Climate change: a call to action for the United Nations. *Allergy* 77, 1087–1090. doi: 10.1111/all.15079

Neumayer, E. (2000). In defence of historical accountability for greenhouse gas emissions. *Ecol. Econ.* 33, 185–192. doi: 10.1016/S0921-8009(00)00135-X

Pandey, P., and Pandey, M. M. (2021). Research methodology tools and techniques. Romania: Bridge Center.

Romanello, M., Di Napoli, C., Green, C., Kennard, H., Lampard, P., Scamman, D., et al. (2023). The 2023 report of the Lancet Countdown on health and climate change: the imperative for a health-centred response in a world facing irreversible harms. *Lancet* 402, 2346–2394. doi: 10.1016/S0140-6736(23)01859-7

Ruiz-Martínez, G., Silva-Casarín, R., and Ruiz-Martínez, G. (2013). Comparación morfológica de la costa noroeste del estado de Quintana Roo. *México. Tecnología y Ciencias Del Agua* 4, 47–65.

Sánchez-Núñez, J. M., Serrano Flores, M. E., Sangermán Jarquín, D. M., Navarro Bravo, A., Vera Alejandre, G. R., Cuevas Sánchez, J. A., et al. (2011). Extreme hydrometeorological events and disasters in urban and rural communities in Motozintla. *Chiapas. Revista Mexicana de Ciencias Agrícolas* 2, 167–181.

Sandoval-Ayala, N. C., and Soares-Moraes, D. (2015). Vulnerabilidad y activos familiares frente a riesgos. caso de estudio en Ixil, Yucatán. *Revista LiminaR. Estudios Sociales y Humanísticos* 13, 56–68.

United Nations. (2021). Climate change and the environment. Available online at: <https://news.un.org/es/story/2021/09/1496142#:~:text=El%20cambio%20clim%C3%A1tico%20y%20los%20fen%C3%B3menos%20meteorol%C3%B3gicos%20cada,para%20la%20Reducci%C3%B3n%20del%20Riesgo%20de%20Desastres%2028UNDRR29>

World Meteorological Organization (2023). WMO atlas of mortality and economic losses from weather, climate and water extremes (1970–2019). Geneva: World Meteorological Organization.