Analysis of risk and disaster reduction strategies in South American countries

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Abstract

There is a growing interest in disaster risk management due to an increasing vulnerability to extreme natural events and man-made disasters that prevent normal relations in societies worldwide. Thus, this study aimed to analyze disaster risk reduction (DRR) strategies in the context of seven Spanish-speaking South American countries, namely Argentina, Bolivia, Colombia, Chile, Ecuador, Paraguay, and Peru. We conducted an analysis of different DRR plans by using text mining techniques. Textual processing of the DRR strategies was conducted using computer-assisted qualitative data analysis. This process was complemented with the use of statistical models, such as the hierarchical cluster analysis and multiple correspondence analysis. Among the main results, 87 DRR strategies were found in the selected countries. The categorization of these strategies were different based on four management planning elements: planning based on social participation and stakeholder management, management planning based on disaster response, post-disaster continuity management planning, and management planning of essential sector continuity. Thus, this paper highlights the region's strengths and weaknesses and serves as a basis to follow up on the 2030 agenda for DRR discussed at Sendai in 2015.
Keywords: Disaster risk reduction strategies, Sendai Framework for Disaster Risk Reduction 2015-2030, Text mining, Qualitative data analysis, Hierarchical cluster analysis, Multiple correspondence analysis

1. Introduction

A crisis event "...is essentially an infringement upon the centralized order of a space or in remote areas, and an indicator of what happens when you lack the benefits of this order" [1]. The consequences include a disruption of behavior patterns and routine relationships in society [2], as well as damages and losses that these incidents entail for human beings [3].

According to the United Nations Office for the Coordination of Humanitarian Affairs, the Latin American region is the second most prone to natural hazards worldwide [4]. This is due to the location of this region in the Pacific Ring of Fire which exposes it to a series of phenomena, such as floods, earthquakes, and volcanic eruptions [5, 6, 7, 8]. During 2015–2019, geophysical[1] and climate change-related[2] natural extremes affected 35.52 million people in this region, causing 4,770 deaths and resulting in an estimated economic cost of 111,545 million dollars [9].

In response to this, a series of international agreements related to sustainable development, increasing resilience to disasters, and reducing poverty were established in 2015, with effect for the next 10 to 15 years [10]. In the context of reducing risks and strengthening resilience to disasters, the Sendai Framework for Disaster Risk Reduction (SFDRR) was developed [11].

The SFDRR's goal E seeks to considerably increase the number of countries that have disaster risk reduction (DRR) strategies at the national and local levels by 2030 [11]. This global agreement was signed by 187 countries and presents several important gains for the framing of international and national policy before, during, and after a disaster [12].

The development and implementation of DRR strategies allow different topics to be addressed, such as risk assessment, prevention, or mitigation [13]. Several of these strategies, which are commonly included in the"DRR plans" of

[1]Earthquakes, volcanic eruptions, or dry mass movement

[2]Storms, floods, wet mass movement, extreme temperatures, droughts, and fires

many countries, have been studied in particular cases [14, 15]. However, few studies have comprehensively analyzed DRR strategies [16].

A comprehensive analysis of DRR strategies offers numerous benefits such as i) knowing the DRR efforts undertaken by regional policy [13], ii) understanding vulnerability to risks, iii) making comparisons between similar countries, iv) checking the conformity of disaster management systems of different countries with a related contemporary international framework [17], such as the SFDRR 2015–2030, v) generating knowledge for decision making [18], and vi) serving as input to accelerate the implementation of strategies in the context of DRR [19].

Thus, we aim to analyze the comprehensiveness of the proposed DRR strategies in different DRR plans in the context of Spanish-speaking countries in South America (sscSA). The specific objectives are as follows:

– Analyze the DRR efforts in South American countries under a risk-based categorization according to the SFDRR and International Organization for Standardization (ISO) 9001:2015 standards.

– Provide a global image of the implemented strategies in these countries. This aim was carried out through descriptive analysis and a hierarchical cluster analysis.

– Characterize the countries analyzed according to the DRR strategies implemented from a reduced dimension perspective using the multiple correspondence analysis (MCA) technique.

To achieve these aims, we review the DRR strategies found in the DRR plans of seven sscSA: Argentina, Bolivia, Colombia, Chile, Ecuador, Paraguay, and Peru. Venezuela and Uruguay were not considered because their DRR plans were not found on the institutional websites of their DRR agencies when we searched for these documents.

2. Disaster risk reduction strategies and case study

2.1. Disaster risk reduction strategies

The main inputs for this study were DRR strategies, which are government intentions that summarize and outline DRR and translate it into concrete risk management policy measures. The main objective of these measures is to increase resilience and support sustainable development, giving rise to national DRR plans [15].

These strategies are aimed at different types of hazards, such as floods, earthquakes, and epidemics. Among other aspects, they include risk diagnosis, administrative and organizational capacity, and the technical and financial resources available to manage the different disaster phases [20].

Many of these strategies are traduced on planning and prior preparation; however, the damage and disasters that arise unexpectedly are improvised on depending on citizens' preparation degree and the local authority [21]. Thus, the more improvisation, the greater the risk of losses (social or economic) and the more difficulty in returning to normalcy [22].

Consequently, DRR strategies are a valuable instrument that seek to prepare the DRR national system of each country as a single structure [23]. The objective of a DRR system is to integrate actions and articulate the functioning of governmental and nongovernmental organizations (NGOs) and civil society to strengthen actions aimed at reducing risks [24].

Fig. 1 depicts the basic structure of a DRR system using the case of Colombia (included in this study) as a reference. Among the essential elements, a leader who coordinates a set of actors and manages resources at different regional and hierarchical levels to reduce risks and damages (in this case, the president of Colombia) is emphasized. It also highlights the existence of a coordinating entity for the entire national system (in this instance, the National Unit for Risk and Disaster Management) that directs the development and implementation of policies aimed at improving knowledge, reducing risk, and managing damage [25].

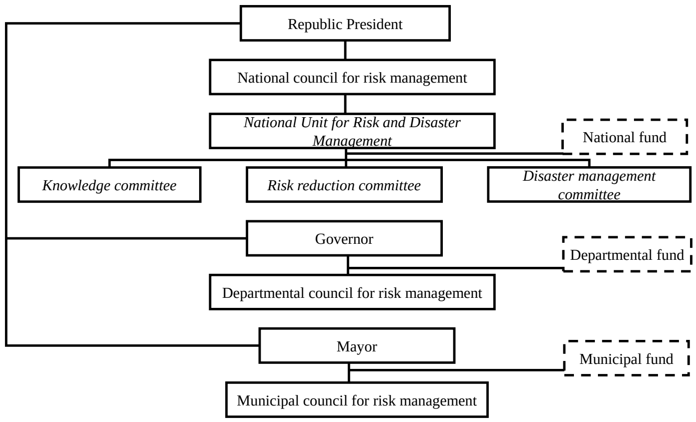

Fig. 1. National Disaster Risk Management System of Colombia [25].

In the seven analyzed countries, each country has its own DRR system (except for Paraguay, which plans to implement it with the DRR plan analyzed in this study [26]), DRR plan, and DRR strategies. The coordinating entities belonging to Argentina, Bolivia, Peru, and Chile are affiliated with some public entity, such as ministries of security and defense [24, 27, 23, 28]. Alternatively, Colombia, Ecuador, and Paraguay have greater autonomy as they are decentralized or affiliated directly with the presidency [29, 30, 26].

It is emphasized that DRR strategies do not have a “standard” coding framework that allows their collection, dissemination, and analysis, unlike other social areas that allow the use of standard classifications, for example, the International Standard Industrial Classification of all economic activities or the International Classification of Diseases and related health problems [31, 32]. Furthermore, DRR strategies are stipulated in the form of sentences or paragraphs with different writing styles, which makes it difficult to conduct regional comparisons.

Therefore, having an inventory of DRR strategies would allow for, among other things, local and regional comparisons on DRR planning [13]. In addition, it would enable the expansion of the portfolio of local DRR strategies when facing different extreme events. In this study, we have called the analysis of the total inventory of DRR strategies the "comprehensive strategy analysis."

Among the international agreements addressing the impact of disasters in a planned way, the SFDRR 2015–2030 promoted by the United Nations, is prominent [11]. In the present study, this framework, through its four priority areas, facilitated the inventory or classification of DRR strategies in an orderly and comprehensive way.

It should be noted that this framework has been criticized for its technocratic character to understand risks [33]. That is, it is not designed to understand human behavior that is reflected in the social, economic, and political structure of society as causal factors of vulnerability to disasters [33]. In this sense, the present study complemented the DRR categorization proposed by the SFDRR with a standard risk management-based categorization of a quality management system called ISO 9001:2015 [34]. However, the development and implementation of these kinds of strategies are sometimes restricted by a series of local obstacles [15]. Consequently, the efforts that were undertaken by regional policy did not achieve an effective response to a crisis event, despite international interest [13].

Therefore, the main barriers that limit the implementation of DRR strategies are legislative requirements, local governments lack of awareness about their importance, as well as social and cultural aspects [35]. From this perspective, the need for studies that contribute to DRR advancement and sustainable development remains [36].

2.2. The case study

The study was limited to the sscSA where it was possible to find DRR plans on their respective government platforms, specifically the seven sscSA listed in Table 1. The literature suggests that natural extremes are initiators of a disaster, but they are not the cause [37].

In this regard, Table 1 and Table 2 present metrics to understand the impact of disasters in sscSA. Table 1 presents 15 indicators on disasters and the DRR plans analyzed in the sscSA. Table 2 presents one indicator based on the average

Table 1: Disasters' impact in South America for the period 2015–2019 [9].

Metric	Argentina	Bolivia	Chile	Colombia	Ecuador	Paraguay	Peru
Economic cost of disasters (1) (Millions of dollars (US$))	4,419	450	3,552	104	2,010	NA*	3,296
Population total (Thousands)** (2)	43,075	10,870	17,969	47,521	16,212	6,689	30,471
GDP per capita (current US$)***	9,912	3,552	14,897	6,429	6,184	5,415	6,978
Directly Affected people metrics							
Total (Thousands)(3)	384	1,132	901	200	1,358	820	2,613
Percentage(%) ((3)/(2))×100	0.89	10.41	5.01	0.42	8.38	12.26	8.58
Cost per person (Thousands of US$) (1)/(3)	11.51	0.4	3.94	0.52	1.48	NA	1.26
Fatalities metric							
Total (4)	28	116	266	579	708	31	317
Percentage(%) ((4)/(2))×100	0.07	1.07	1.48	1.22	4.37	0.46	1.04
Cost per person (Millions of US$) (1)/(4)	157.82	3.88	13.35	0.18	2.84	NA	10.4
Number of extreme events							
Geophysical	1	2	4	2	5	0	6
Climate change	17	8	11	17	4	9	9
Relative Mortality Risk Index (R-MRI)****							
Global index	4	5	5	8	7	5	7
Floods	3	4	3	4	4	4	3
Landslides	2	4	4	4	4	4	4
Earthquakes	3	4	5	8	7	0	7
D. Risk reduction analyzed plan	[24]	[27]	[28]	[29]	[30]	[26]	[23]

/* NA = Not Available data; /** data from 2015; /*** data from 2019 [38]; /**** data from 2009 [39]
/*** R-MRI legend: 0:Unknown exposure; 1:Negligible; 2:Very low; 3:Low; 4:Medium Low; 5:Medium; 6:Medium high; 7:High; 8:Very high; 9:Major; 10:Extreme

duration of the last 10 leaders of the sscSA (column two), the number of times all leaders were in power (presidential terms column), and the time period of this analysis.

Table 2: Average duration of the last 10 leaders of government in the analyzed countries of South America.

Country (ccTLD)*	Average duration (years)	Presidential terms	Time period
Argentina (AR)	3.16	12	1981 - 2019
Bolivia (BO)	2.94	12	1985 - 2020
Chile (CL)	4.57	13	1958 - 2018
Colombia (CO)	4.00	12	1970 - 2018
Ecuador (EC)	2.40	12	1988 - 2017
Paraguay (PY)	3.57	18	1954 - 2018
Peru (PE)	3.01	15	1975 - 2020

/* ccTLD: Country Code Top-Level Domain.
Data source: [40]

There is evidence to suggest that the frequency of natural disasters increased each year, especially in underdeveloped countries [41]. From this perspective and only considering the gross domestic product (GDP) per capita, Bolivia is the most vulnerable to disasters. Comparatively, Chile is the least vulnerable in the region. Although every phenomenon is not dangerous, some constitute a danger due to their type, magnitude, and their unexpected occurrence [37]. Against this background, Table 1 shows Peru as the country most prone to geophysical hazards and Paraguay as a low-risk country in terms of these type of extreme events. Moreover, Colombia and Argentina appear to be the most and Ecuador the least prone to climate change events, respectively.

The interaction between an extreme geophysical phenomenon and a vulnerable condition translates into economic and human losses [37]. Among the main disaster statistics, Table 1 shows Peru as the country with the most significant impact on people; however, the metric percentage of people affected over the total population shows Paraguay as the most affected. Furthermore, metrics related to fatalities during extreme events show Ecuador as the most vulnerable. All metrics related to economic cost show Argentina as the country with the highest economic cost due to disasters during 2015–2019.

Likewise, the Relative Mortality Risk Index (R-MRI) which is based on modeling hazards (tropical cyclones, floods, earthquakes, and landslides) shows Colombia as having the highest mortality risk according to the detailed hazards [39]. In terms of floods and landslides, most countries have a medium low R-MRI; however, in terms of earthquakes, most countries have a medium or superior R-MRI. Moreover, Paraguay has the lowest R-MRI for earthquakes and for exposure to geophysical events. Additionally, the fact that Paraguay does not disclose data on the economic costs of disasters highlights the difficulty in collecting data on disasters in the context of the sscSA [42, 43, 44].

Furthermore a positive correlation between political instability and disasters has been demonstrated [45]. To illustrate, Table 1 shows that Ecuador has a high R-MRI and is the most unstable country considering the average duration of its last 10 leaders (See Table 2). Comparatively, Chile is the most stable country (Table 2) and has a medium R-MRI (Table 1).

3. Methodology

A graphical representation of the research methodology is displayed in Fig. 2. The R package for Qualitative Data Analysis (RQDA) [46, 47] was used to process the DRR plans and perform the thematic analysis. This package allows any textual material to be encoded and then described or displayed [48]. Additionally, descriptive analysis and advanced statistical modeling accompanied the thematic analysis. Each of the procedures are detailed below.

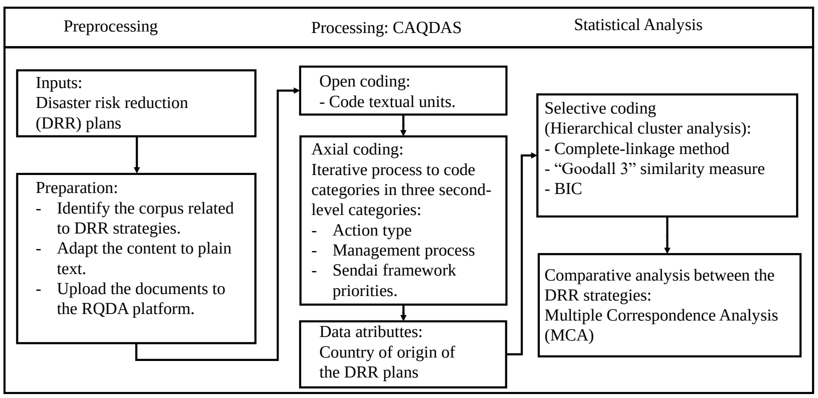

Fig. 2. Graphical Description of the Methodology.

3.1. *Preprocessing*

The preprocess text stages in this study included a search of the different DRR plans in sscSA. As the RQDA supports only plain text (.txt) files, it was necessary to select the textual corpus related to risk reduction strategies in the DRR plans and adapt them to plain text before processing the texts in RQDA [49].

3.2. *Textual processing of the disaster risk reduction strategies*

Textual processing was conducted with an open source Computer-Assisted Qualitative Data Analysis (CAQDAS) based R extension called RQDA, which facilitates the coding of texts and allows for code comparisons [49].

To differentiate between the DRR strategies within the different DRR plans, the three stages of text coding proposed by Gioia were followed [50]. This approach comprises three levels: i) a single process of encoding the textual data (called open encoding), ii) summarizing these themes within a firmer theoretical realm (called axial coding), and iii) the selective aggregation of these themes in aggregate dimensions (known as selective coding) [50].

3.2.1. Open coding

During the open coding phase (first level codes), the DRR plans were thoroughly reviewed to identify the DRR strategies. This analytical process consisted of placing interpretive conceptual labels on the textual data after considering all possible meanings and examining the context carefully [51]. For instance, the phrase included in Ecuador's DRR plan of *Food and non-food aid delivery* [30] was coded as "W1: aid management and food security."

3.2.2. Axial coding

After the coding process was completed, first level codes were aggregated into higher level code categories (called axial coding, abstraction, or second level categories) [49]. This process was consistent with the constructivist theory-building process [49, 51]. This process was carried out iteratively three times [49] giving rise to three second level thematic codes.

This second level thematic classification was based on the SFDRR and the ISO 9001:2015 standard. The SFDRR was chosen for its importance in guiding risk regional policy [10] and the ISO 9001:2015 standard for its practical utility in understanding and managing systems using risk-based thinking concepts [34]. Furthermore, the use of this type of approach was in line with the SFDRR aims, especially with priority two that was related to "the development of quality standards in terms of disaster risk management" [11].

The first abstraction was based on the comparative classification of the first level codes with the set of measures proposed by the SFDRR in its four action priorities [11]. This thematic coding enables the linkage or the existing relationships of the DRR strategies to be seen with the Sendai framework. Thus, all the sentences, phrases, or paragraphs coded as "W1" were related with SFDRR priority three (Section 30j) and priority four (Section 33j) about establishing links for the rehabilitation and development of communities through the application of inclusive policies and social protection mechanisms associated with food security and nutrition [11].

The second abstraction was based on the comparative classification of the first level codes with four key elements of a quality management system according to the ISO 9001:2015 standards. The purpose of using this standard in this study was to complement the understanding of risk reduction strategies as articulated elements of a system. These elements were planning, support, operation, and evaluation of system performance. Unlike the SFDRR, this comparison enabled us to see the strategies as necessary inputs that are articulated and complement each other to establish, implement, maintain, and continuously improve the quality of the DRR system of a country where risks are the base element of this planning [34].

In the case of the "W1" code, the revision of the ISO 9001:2015 standard allowed adding said code as an operational strategy (Sections: 8.1, 8.2 and 8.3) because it was related to planning, legal requirements, and product design and services, in addition to the requirements of communicating with those affected and delivering aid [34].

The third abstraction was based on a common term of the ISO 9001:2015, namely "non-conformity," [34] which is understood as a quality system noncompliance [52] or any failure to meet a requirement [53]. This concept gave rise to the next two categories:

Preventive Actions: DRR strategies aimed at "avoiding" nonconformities or risks materialization.

Corrective Actions: DRR strategies aimed at "eliminating" nonconformities or possible damages caused in the system in case the risk materializes.

Thus, the code "W1" related to aid management was classified as a corrective action because it was aimed at eliminating a non-conformity in the event of a disaster. If the strategy was to "guarantee employment or economic stability during a disaster or emergency to prevent people from starving," it was classified as a preventive action.

Table 3 describes all the second level DRR strategies categorizations made in the processing phase. The first three groups of elements detailed in Table 3 shows the description of the second level thematic coding for the DRR strategies. It is important to highlight that the categorization referring to management processes (option 2 in Table 3) initially comprised four categories. However, due to the low representativeness of the operational and performance evaluation strategies, these two categories were amalgamated.

3.2.3. Data attributes

One of the advantages of using CAQDAS is the possibility of adding data attributes to enrich textual understanding [49]. Using this functionality, the country of origin of the different DRR plans was retained. Part four of Table 3 details the analyzed countries with their respective pseudonym that was the Country Code Top-Level Domain in this study. The preservation of this variable enabled different comparisons of the sscSA.

Table 3: Second level thematic coding of disaster and risk reduction strategies.

Description	Pseudonym
(1) Sendai Framework Action Priorities*	
Disaster Risk Understanding	P1:DRU
Strengthening of risk governance	P2:governance
Investing in risk reduction	P3:investment
Disaster preparedness for response	P4:response
(2) Management process	
Planning actions	M:planning
Support actions	M:support
Operational and performance evaluation actions	M:operational
(3) Action Type	
Preventive actions	A:preventive
Corrective actions	A:corrective
(4) Country of origin*	
Argentina	AR
Bolivia	BO
Chile	CL
Colombia	CO
Ecuador	EC
Paraguay	PY
Peru	PE

/* All the categories are binary variables. The absence of any category is denoted with the concatenation of its pseudonym plus the text ":no." For instance, AR:no denotes the absence of Argentina.

3.2.4. Analysis of the overlap of second level codes

During a textual analysis, an overlap of codes (phenomenon presented in the categorization of the DRR strategies to the SFDRR priorities) can occur [48]. A self-elaboration Overlapping Code Index (OCI) was used (see Equation 1) to assess the degree of overlap, where $\sum_{i=1}^{D} P_{ij}$ is the sum of the strategies related to priority i for country j, n_{ij} is the total number of strategies for country j, and $D = \{1, 2, 3, 4\}$ is the number of total priorities (P).

$$OCI = 1 - \sum_{i=1}^{D} P_{ij} / D * n_{ij} \tag{1}$$

3.2.5. Selective coding

It should be noted that the R Software allows the use of other available functions outside of RQDA that enables a better interpretation of the data obtained, for example, quantitative methods that complement and enrich the analysis of textual data [48, 50]. All DRR strategies (open coding phase) and their categories (Table 3) were represented in a matrix with the DRR strategies in the rows and the categories in the matrix columns. This matrix facilitated the application of a hierarchical cluster analysis (HCA) in the selective coding phase. This process consisted of recategorizing all first and second level code categories into higher level categories [49].

A distance-based method was used to conduct the HCA. The following steps were performed to obtain a grouping model appropriate to categorical data: i) selecting a suitable similarity or distance [54], ii) selecting a classification algorithm [55], and iii) determining the optimal number of groups based on statistical criteria [56].

When selecting for similarity, the set of measures for categorical data offered by the "nomclust" package [56] were considered. This type of similarity is advantageous as it leads to "better" clustering compared with other measures, such as those that are binary transformed [57].

The calculation of similarities by this method requires assigned weights w_k

and a similarity function $S_k(X_k, Y_k)$ that measures the similarities or differences between the instances X and Y within the categorical attributes A_k. Therefore, considering the term d as the total number of categorical attributes, the function $S(X, Y)$ of these similarities was described as:

$$S(X,Y) = \sum_{k=1}^{d} w_k S_k(X_k, Y_k) \tag{2}$$

Moreover, the selection of the classification algorithm was determined by three clustering methods: i) single-linkage clustering, ii) complete-linkage clustering, and iii) group-average clustering. First, each member or unit (strategies in the present study) was considered as a single group of a unitary set. Then, the units that had the most remarkable similarity were grouped. Finally, this process was conducted in several stages, until the endpoint was reached where all DRR strategies were combined into a single group [58].

Although these classification algorithms were quite similar, they differ in the way they characterize the similarity between a pair of groups [55]. To illustrate, the single-linkage method defines the similarity (dissimilarity) between two clusters as the most similar pair (similarity) (least dissimilar) [58, 55]. Moreover, the complete-linkage algorithm defines the distance between two groups as the maximum of all the distances between all the pairs extracted from the two groups [55], that is, the least similar (most dissimilar) pair [58]. Lastly, the group-average method defines the distance as the average of the distances between the pairs that make up each group [58].

The third step was to determine the optimal number of groups based on statistical criteria [56]. In this context, the "nomclust" R package offered some indices to make this contrast. Some of them indicate the optimal number of clusters by its maximum value among various clustering solutions examined [59], namely the Pseudo F Index based on Mutability, the Pseudo F Index based on Entropy, and the evaluation criteria of the BK index. Contrastingly, others establish the optimal number of clusters for the minimum value, namely the Bayesian Information Criteria (BIC) and Akaike Information Criteria [59].

Overall, the BIC index determines the optimal number of the cluster better than the other proposed evaluation criteria [59]; thus, this criterion was given more importance.

The hierarchical agglomerative technique that best grouped our data (which is detailed in Table 3) was determined by combining the 12 similarities proposed by the "nomclust" package with the three grouping methods that fit the minimum BIC index of all combinations according to Fig. 3.

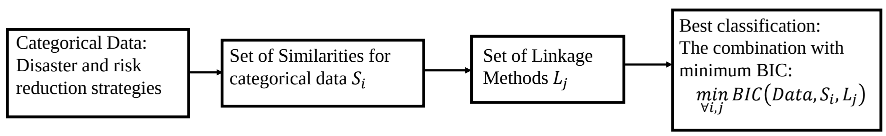

Fig. 3. Hierarchical Cluster Analysis Process.

Thus, the present study proposed an HCA fitted by the complete-linkage method and the "Goodall 3" proximity, which is a variant of the original Goodall measure [54]. The main characteristic of this measure is the allocation of more significant dissimilarity when the categories with little frequency coincide (match) independently of the frequencies of the other categories [54, 56]. This similarity function and its weights are denoted as

$$S_k(X_k, Y_k) = \begin{cases} 1 - p_2^k(X_k), & \text{if } X_k = Y_k \text{ with } w_k = {}^1/_d, k \\ 0, & \text{otherwise} \end{cases} \tag{3}$$

where the function $p_2^k(X_k)$ is an estimated probability of the attribute A_k when it takes the value X_k in a data set.

3.3. Multiple correspondence analysis

An MCA was conducted to provide an overview of the relations between the different countries and the characteristics associated with the different DRR strategies.

This model allows researchers to summarize large amounts of information into a small number of dimensions or factors [60]. In this way, the similarities between the DRR strategies are transformed into distances that can be represented in a multidimensional space [60]. Consequently, it enables the description of structures or patterns in the relations between variables that would otherwise be difficult to discover [60].

The mathematical description of this model begins with a matrix composed of K nominal variables, where each nominal variable has $\mathsf{J_k}$ categories and the sum of $\mathsf{J_k}$ is equal to j. Furthermore, there are I observations which, in our case, were the DRR strategies. This $\mathsf{I} \times \mathsf{J}$ matrix is denoted as X. The entire table is described as N and the first step is calculating the probability matrix $\mathsf{Z} = \mathsf{N}^{-1}\mathsf{X}$ [61].

Denoting r as the vector of the total rows of Z, (e.g., $\mathsf{r} = \mathsf{Z}\mathsf{1}$) with $\mathsf{1}$ as the vector of ones, c as the vector of total columns, and $\mathsf{D_c} = \mathsf{diag}\{\mathsf{c}\}$, $\mathsf{D_r} = \mathsf{diag}\{\mathsf{r}\}$. The scores' factors are obtained from the following singular value decomposition,

$$\mathsf{D_r^{\frac{1}{2}}}(\mathsf{Z} - \mathsf{rc^T})\mathsf{D_c^{-\frac{1}{2}}} = \mathsf{P\Delta Q^T} \quad (4)$$

with Δ as the diagonal matrix of singular values, and Z and Q as singular value decomposition matrices. The scores used to interpret this model are given by the row and column factors, which are respectively denoted as:

$$\mathsf{D_r^{-\frac{1}{2}}}\mathsf{Z\Delta} \text{ And } \mathsf{G} = \mathsf{D_c^{-\frac{1}{2}}}\mathsf{Q\Delta} \quad (5)$$

4. Results

4.1. Descriptive Analysis

Through the *open coding* textual analysis conducted with CAQDAS on the different DRR plans, a total of $N = 87$ DRR strategies were collected. Four second level thematic codes were implemented in RQDA to characterize these strategies (see Table 3). Regarding the country of origin, the percentage share was high in Peru (56%), Colombia (55%), and Ecuador (54%), followed by Argentina (37%), Paraguay (34%) and Chile (34%), and the least in Bolivia (21%).

The thematic coding analysis on *action type* showed that 78% of DRR strategies were aimed at reducing risks (preventive strategies), while 22% were aimed at eliminating nonconformities or problems arising during a disaster.

According to the thematic coding management process, the 87 DRR strategies were structured between planning (39%), support (38%), and operational management and evaluation (23%). The SFDRR's thematic coding analysis showed that 53% of DRR strategies were aligned with priority one (P1: Disaster risk understanding), 43% with priority two (P2: Strengthening of risk governance), 57% with priority three (P3: Investing in risk reduction), and 75% with priority four (P4: Disaster preparedness for response).

Table 4 shows the percentage relation of the DRR strategies found for different countries analyzed according to the different risk thematic categorizations. Column one describes the thematic categorizations using the axial coding process and the total (n) of DRR strategies for each category. The remaining columns indicate the percentage of strategies for each country with respect to the total in its category (n).

Table 4: Percentage participation (%) of the $N = 87$ DRR strategies found in South America considering their thematic characterization.

Thematic (Total DRR strategies)	Argentina	Bolivia	Chile	Colombia	Ecuador	Paraguay	Peru
	(%)**	(%)	(%)	(%)	(%)	(%)	(%)
Action Type							
Preventive (n = 68)	40	26	40	62	43	38	57
Corrective (n = 19)	26	0	16	32	95	21	53
Management process							
Planning (n = 34)	41	12	24	59	41	29	56
Support (n = 33)	33	36	55	61	48	39	55
Operational and evaluation (n = 20)	35	10	20	40	85	35	60
Sendai Framework Priorities							
Disaster risk understanding (n = 46)	46	26	54	67	46	52	67
Strengthening of risk governance (n = 37)	54	32	41	70	41	43	68
Investing in risk reduction (n = 50)	32	10	20	58	52	32	52
Disaster preparedness for response (n = 65)	40	23	35	49	66	35	62
Total DRR strategies (N = 87)	37	21	34	55	54	34	56

/** The percentages were computed dividing the number of DRR strategies of the respective thematic categorization and country by its total (n).

4.2. Classification of disaster risk reduction strategies

An HCA was fitted to group the DRR strategies according to their associated characteristics. The first column of Table 5 represents five quality criteria required to select the optimal number of clusters.

The remaining columns display the value of different criteria (index) and the optimal number of clusters proposed according to three classification methods (single, complete, and average) as per the "Goodall 3" similarity measure.

Accordingly, the single-linkage method was optimum with five groups (favorable position), the group-average method with two clusters (conservative position), and the complete-linkage method with four groups.

Table 5: Selection of the optimal number of clusters using the *Goodall 3* similarity measure.

Method (Optimum)	Single-linkage		Complete-linkage		Group-average	
	ONC*	index	ONC	index	ONC	index
Akaike Information Criteria (min)	1	1,548.30	6	1,124.48	6	1,125.48
Bayesian Information Criteria (min)	1	1,582.82	4	1,301.92	5	1,315.42
BK index (max)	5	0.20	4	0.97	2	0.72
Pseudo F entropy index (max)	5	1.41	4	12.32	2	14.70
Pseudo F mutability index (max)	5	1.38	4	14.12	2	16.23

/* ONC: Optimal number of clusters.

The BIC has been shown to be a robust indicator to determine the optimal number of clusters [59]. According to Table 5, this index was at its minimum when four groups were estimated by the complete-linkage method (this combination was the optimal selection in this study). It was interesting that when using four clusters with the complete-linkage method, 80% of the 5 criteria exposed agreed in contrast to 60% when using the other 2 methods.

In this way, the HCA facilitated the selective coding of the DRR strategies into four groups. This classification of the DRR strategies not only takes into consideration the recommendations of the SFDRR, but also addresses the systemic nature of DRR strategies by including standard categories related to DRR management processes in the analysis.

Once the model was estimated, a name was assigned to each cluster through a detailed textual review of each element. For a better understanding of this structure, each cluster was subdivided into four parts considering the four most important partitions or subclusters. Tables 6 and 7 present the name of each cluster, subcluster, and its respective identifier code.

Table 6: Component description of *Disaster management planning* (cluster 1) and *Risk management, knowledge, and communication* (cluster 2).

(C1) Disaster management planning
1.1 Health of those affected Rescue and prehospital care, care for priority and vulnerable groups; psychosocial and mental health support; management of aid and food security; restoration of basic services, livelihoods, and security in the affected area.
1.2 Spaces recovery Management of vulnerable areas impacted by the disaster. Among other things, prioritization of vulnerable areas, management of orphans, human remains, evacuation, and temporary accommodation.
1.3 Response management Activation of alert and demobilization of the response, monitoring of the management and control of humanitarian actions, the demolition of waste / rubble and the protection of human rights.
1.4 Economic and social assistance Management of public contingency funds, reimbursable and non-reimbursable credits; optimization of customs processes in times of crisis.
(C2) Risk management, knowledge and communication
2.1 Risk mitigation Risk management of heritage areas, signage for human displacement, improvement of blood banks; use of environmentally sustainable technology and linkage and articulation of risk with the research field.
2.2 Risk management of strategic sectors Management and incorporation of risks in different strategic sectors, such as agriculture and tourism, and according to different dangers, such as the agglomeration of the public and bio sanitary and socio-technological phenomena.
2.3 Development and use of risk knowledge Development of scientific capacity on disaster risk management; provision of technical assistance and development of training programs to incorporate knowledge of risk.
2.4 Communication and response Communication continuity management, dissemination of the response plan and findings, mass media management, communication management for the management and safety of volunteer teams and response workers.

Table 7: Component description of *Strengthening and articulation of actors* (cluster 3) and *Risk governance* (cluster 4).

(C3) Planning of strengthening and articulation of actors
3.1 Risk and damage assessment Strengthening of risk assessment and territorial reorganization of vulnerable settlements. During a disaster, assessment of the continuity of essential sectors, evaluation of the socioeconomic impact of the emergency, and assessment and attention to the needs of the population.
3.2 Disaster preparedness Strengthening of international cooperation, the medical sector, and the necessary equipment; incorporation of risk in the planning of public entities; preparation of plans to manage risk in ethnic and intercultural groups; risk mitigation against natural, Environmental, and climatic hazards; promotion of laws and regulations for action.
3.3 Articulation of internal and external actors. Assisted commonwealth and interdepartmental cooperation; incorporation of the health sector, private sector, households in the urban sector, rural sector; and the evaluation and monitoring team of natural extremes.
3.4 Continuity assurance Strengthening of institutional capacities and resources for the response, the implementation of operating licenses with a DRR approach and risk transfer instruments, such as the activation of insurance policies. Promote alternative systems that allow the socioeconomic continuity of vital services such as water and sanitation.
(C4) Risk governance planning
4.1 Risk management mechanisms Availability of technology for the articulation and dissemination of information; evaluation, monitoring, risk detection, early warnings; instruments for citizen participation and prevention, in addition to the education and training of professionals.
4.2 Exchange of experiences Promotion of activities that promote the exchange of experiences on DRR with respondents and strengthening of communication through information communication technologies.
4.3 Two-way communication with the community Two-way communication strategy that sensitizes people and incorporates traditional and ancestral ethnic knowledge about DRR.
4.4 Risk management culture Knowledge development about DRR in the community.

4.3. Comparative analysis between South American countries

An MCA was conducted to understand the relations between characteristics associated with strategies and countries. To interpret the data, a biplot analysis of the first two components (40.6% inertia explained) was utilized.

The biplot facilitates the interpretation of correlations between variables through dimensionality reduction [62]. The variable contribution to the poles from different axes is displayed in Fig. 4. The more distant a variable is from the neutral point (0,0), the better it is represented by the analysis. Comparatively, the categories close to the center play a minor role in the biplot [62].

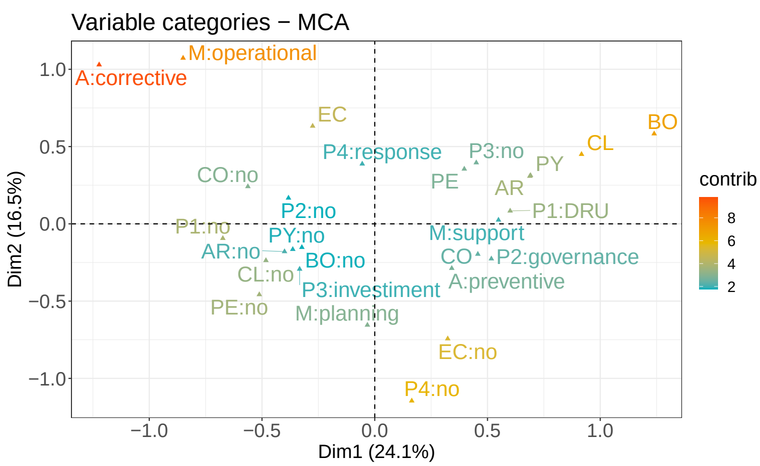

Fig. 4. Variables' representativeness in two dimensions of the MCA. The higher the contributions (contrib), the better the categories are represented. The variable categories refer to second level thematic coding (country of origin, SFDRR priorities, action type, and management process) which are given in Table 3.

The factor map is another tool that complements the above analysis since it aids the understanding of the variable relationships. For instance, Fig. 5 shows a representation of Bolivia together with the second level codes of *action type* and *operational and performance evaluation*. The factor map shows some deficiencies in Bolivia's strategic planning, such as omitting a lot of corrective actions (A: corrective), planning actions (M: planning), and operational and performance evaluation (M: operational). Thus, this analysis clarifies why Bolivia is more represented in the first quadrant of the MCA as well as the distribution of the *action type* and *management process* categories in the biplot.

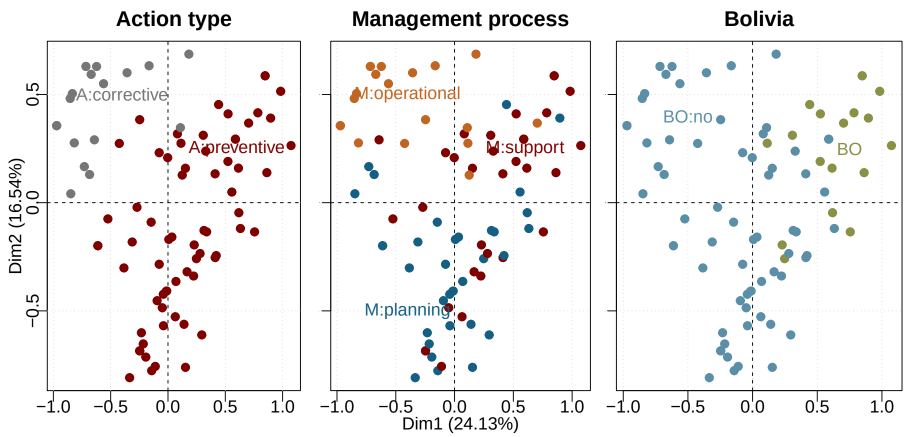

Fig. 5. Factor maps to understand Bolivian relationships with the action type and *management process* categories using the first two dimensions of the MCA. Bolivia was considered in this plot as it was the country with the lowest Gross Domestic Product (GDP) per capita according to Table 1 and to clarify its correlation within the MCA biplot of Fig. 6. Variable categories are detailed in Table 3.

Hence, by analyzing the variables direction in the biplot as well as the analysis of the contributions, the factor map, the HCA, and the individual definition of the DRR strategies using open coding CAQDAS, each quadrant of the MCA biplot was defined:

- Quadrant I: Planning based on social participation and stakeholder management
- Quadrant II: Management planning based on disaster response
- Quadrant III: Post-disaster continuity management planning
- Quadrant IV: Management planning of essential sectors continuity

It is also important to highlight that quadrant I is opposite to quadrant III and quadrant II is opposite to quadrant IV. This is because the variables correlate positively in the direction of their estimated values, but negatively in the opposite direction [62].

4.3.1. Planning based on social participation and stakeholder management (quadrant I)

The MCA shown in Fig. 6 allowed us to see interactions between the clusters established through the HCA, thus allowing us to clarify the management of risks and disasters in the sscSA. Thus, quadrant I (positive Dim1 and positive Dim2) was best represented by the variable related to priority one (P1: DRU) of the SFDRR, which was related to disaster risk understanding.

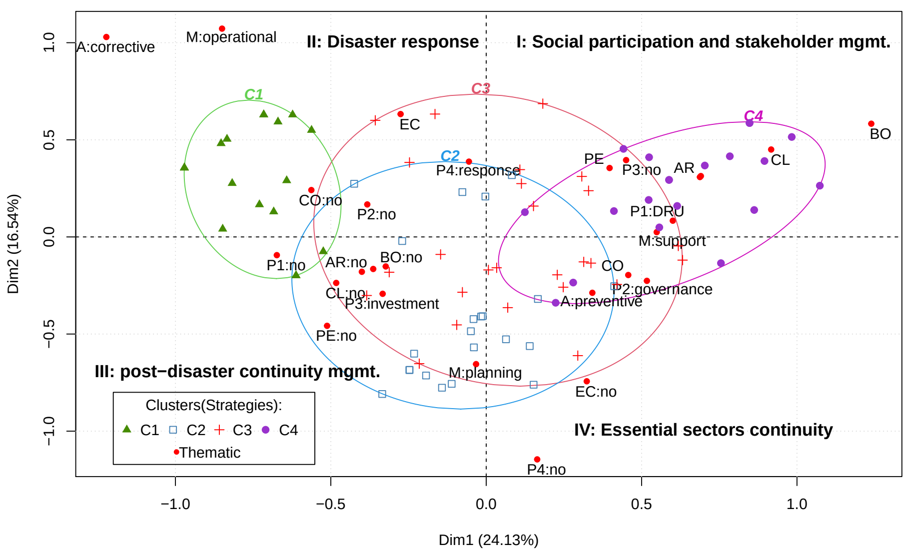

Fig. 6. Biplot of the MCA and the four clusters obtained with the categorical HCA. C1: Disaster management planning, C2: Risk management, knowledge, and communication; C3: Planning of strengthening and articulation of actors; C4: Risk governance planning. Variable categories are detailed in Table 3.

Contrastingly, part of the HCA cluster four (C4), namely "risk governance planning," was linked to this quadrant, specifically, communication and the establishment of relationships with social and strategic actors. Similarly, the HCA cluster two (C2) of "risk management, knowledge, and communication" interacted with the volunteer management strategy and with strategies on stakeholder management, such as international aid management. Moreover, the principal coordinates of Bolivia, Chile, Paraguay, Argentina, and Peru were more related to this quadrant.

4.3.2. Management planning based on disaster response (quadrant II)

According to the MCA principal coordinates, Ecuador was more associated to quadrant II (Fig. 6). This quadrant was best represented by operational and performance management strategies (M: operational), the corrective actions thematic categorization (A: corrective), priority four related to disaster preparedness for response (P4: response), and the HCA cluster one (C1) of "disaster management planning." Within the "planning of strengthening and articulation of actors" (HCA cluster three [C3]), it was associated with strategies such as assessment and attention to the needs of the population or the performance of post-disaster recovery studies. It also took variables from the HCA C2 associated with communication. Among which were strategies to improve mass communication in disaster situations, access to information, and dissemination of findings.

4.3.3. Post-disaster continuity management planning (quadrant III)

Quadrant III of Fig. 6 was mostly identified with the interaction of some strategies from C2 and C3 closely tied with post-disaster continuity management planning. This management type aims to strengthen the socioeconomic continuity of the affected area and promotes the protection of strategic sectors, such as the tourism and agricultural sectors, with an emphasis on vulnerable groups. Also, some DRR mechanisms, such as risk licenses, strategic alliances, or activations of insurance, were linked to post-disaster continuity. Interestingly, no country represented this management type.

4.3.4. Management planning of essential sectors continuity (quadrant IV)

This management planning type represented the country of Colombia. Quadrant IV (positive Dim1 and negative Dim2) of Fig. 6 was identified with the SFDRR priority of strengthening governance and the thematic categorization of preventive actions. Furthermore, it formed part of the HCA C4 of "risk governance planning" related to developing technology and focused on the implementation of early warning systems and risk management centers.

Within the important sectors, the continuity of essential services, such as water, electricity, sewerage, or transport was sought.

This management type was also associated with strategies on the protection of heritage areas, increased knowledge of risk, and the incorporation of external technical assistance for risk management.

5. Discussion

5.1. Open coding

Although the textual processing of the different DRR plans through this phase allowed us to identify the planning for DRR in the seven sscSA, these textual elements should be addressed meticulously. This is especially relevant with terminology as it can lead to misinterpretations and can create a barrier in the development of the research field [63].

For example, the wrong use of the term "natural disasters" to refer to "natural hazards" or "natural extremes" still forms part of the different disaster plans of the sscSA [24, 27, 28, 29, 30, 26, 23]. This demonstrates how, on the one hand, a lack of specialized personnel in the construction of this type of strategic documents exist; on the other hand, the inconclusive encounter that these countries have in changing paradigms, ways of perceiving, and ways of addressing disasters is also evident [37].

5.2. Axial coding

This section encourages discussions around the development and implementation of DRR strategies in the sscSA. For this purpose, we have used the information shown in Fig. 7, Fig. 8, and Fig. 9.

Fig. 7A shows, in decreasing form, the number of strategies implemented in each country of the region and highlights the importance of preventive actions over corrective actions. Additionally, it shows Ecuador has a higher proportion of corrective actions (38%) compared to the other countries. This could be due to a post-crisis measure implemented in response to the earthquake of magnitude 7.6 that impacted this country in 2016 [64].

That is, Ecuador did not have a DRR public access plan before 2016 and general references were used to guide their actions [65]. These basic references focused on strengthening volunteering, the development and socialization of minimum standards and methodologies, the implementation of international co-operation mechanisms, and the operation of the decentralized National System for Risk and Disaster Management [65].

After the 2016 earthquake, Ecuador has recognized not only the importance of strengthening response capacities, but also the need to implement interinstitutional coordination and cooperation actions. Furthermore, they are more aware of the multidisciplinary nature of such coordination and the dynamics of studying crisis events [30].

Contrastingly, the metrics about disaster and risk displayed in Table 1 and the average of presidential duration exposed in Table 2 were correlated with the count of DRR strategies of all the analyzed countries. Fig. 7B shows the correlations greater than 0.50. The analysis of these metrics indicates a correlation $>= 0.70$ between the number of DRR strategies and the variables associated with disaster mortality, such as R-MRI, total fatalities, and R-MRI related to earthquakes. To a lesser extent, correlations with variables related to the number of geophysical extreme events and population total are evident. The correlation analysis also highlights the importance of the occurrence of geophysical extreme events, such as earthquakes, for the preparation of DRR strategies. The remaining metrics displayed in Table 2, such as GDP per capita or R-MRI, related with floods and landslides have correlations $<= 0.50$.

Fig. 7C complements the correlation analysis for the metric regarding fatalities. It shows the linear relations between the strategies collected and the number of fatalities due to disasters during 2015–2019. This relation reflects the commitment of different countries to DRR; however, this commitment is proportional to disaster effects (number of fatalities); thus, a country tends to prepare better depending on the impact of previous disasters.

The exception to this logic was Bolivia, which has given little importance to the risks to date concerning the sustained effects of disasters. However, Peru has implemented more DRR strategies concerning existing problems. Thus, this analysis is consistent with previous studies suggesting that this country is highly committed to risk reduction [16].

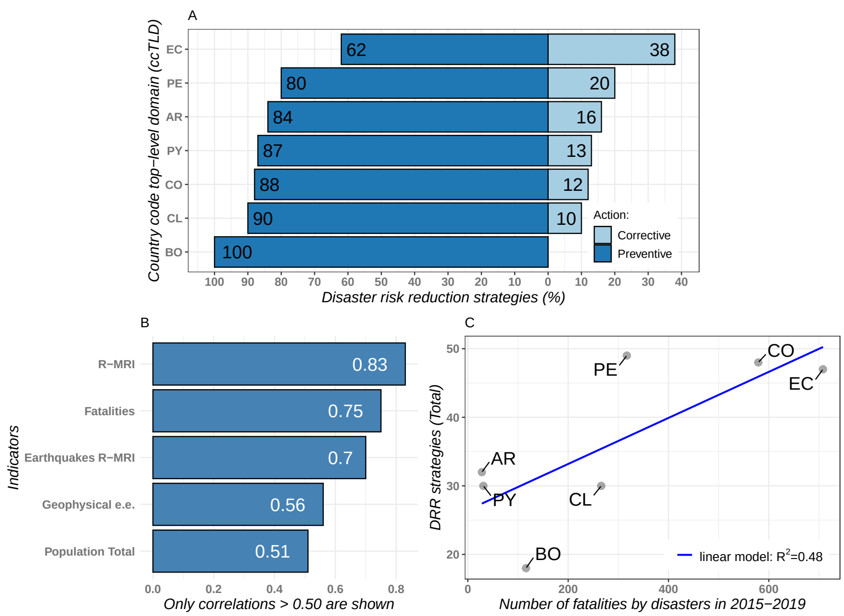

Fig. 7. DRR strategies disaggregated by action type (part A). Count DRR strategies by country correlated with DRR metrics R-MRI, number of fatalities, R-MRI for earthquakes, geophysical extreme events, and population total (PT) (part B, see Table 1). Linear model to explain DRR strategies with the metric number of fatalities (part C).

Additionally, the alignment of DRR strategies with the priorities of the SF-DRR was analyzed. Fig. 8A shows that more than 65% of the strategies were focused on priority four (P4: disaster preparedness). Second, the majority were associated with understanding risk (P1 $>$ 60%), whereas strengthening governance and investment (i.e., priorities two and three) were considered to a lesser extent (P2 $\sim$ P3 $>$ 50%).

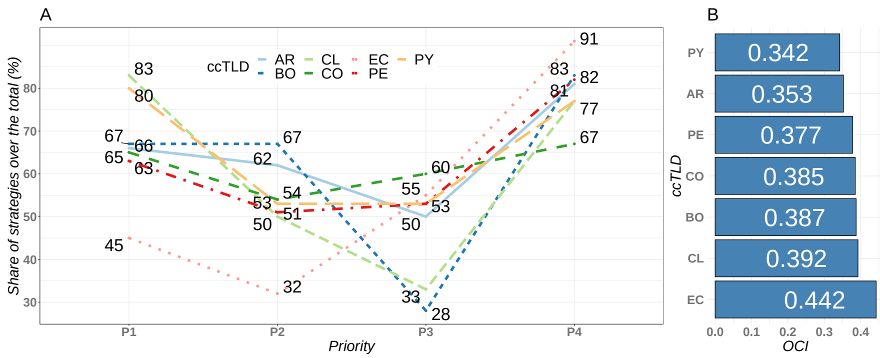

Fig. 8. Share of strategies over the total versus Sendai priorities (part A). Overlapping Code Index (OCI) (part B).

In contrast, Ecuador gave less importance to understanding risk (P1 = 45%) and risk governance (P2 = 32%), but was more aligned with disaster preparedness (P4 = 91%). This finding is justified as their risk and disaster plan mentions a specific focus on disaster preparedness (P4) [30]. However, despite only focusing on this priority, interactions with other priorities were observed. This reveals that, according to the SFDRR approach, DRR strategies are not mutually exclusive and are closely related to each other.

Additionally, Bolivia and Chile had fewer strategies that focused on investing in risk reduction (P3). In the case of Bolivia, it is expected that there are fewer investment-focused strategies for risk reduction (28%) because they still consider risk reduction as an expense and not an investment [27]. Thus, the efforts of its risk reduction plans are aimed at consolidating the importance of a preventive culture to later align with other SFDRR priorities [27], such as investment.

Comparatively, Chile is one of the most seismic countries in the world as they are vulnerable to almost all types of natural and man-made threats [28]. Its DRR plan superseded the priority actions of the 2014–2015 plan related to the Hyogo 2005 framework [28]. Thus, it is justified that it has fewer investment strategies (33%) compared to the other countries since its DRR plan for 2015–2018 proposes only one priority axis focused on reducing the underlying risk factors of the five implemented axes [28]. This reduction translated to an increase in priorities on risk understanding (P1) and disaster preparedness (P4) (See Fig. 8).

An interesting phenomenon manifested in the variable associated with the SFDRR priorities where there was an "overlap of codes" between priorities, which is a common phenomenon of text mining [48]. For this effect, an OCI was used (see Equation 1). When this value was closer to zero, more overlap was present. It was found that the strategies overlapped more in Paraguay (a country that developed its DRR plan with the help of the United Nations Development Program) and less in Ecuador (a country that chose to focus only on priority four). Ecuador is noteworthy because even though its strategic plan focused on priority four of the SFDRR, these DRR strategies overlapped with other priorities.

Finally, the ternary diagram (based on the categorization inspired by ISO 9001:2015) shown in Fig. 9 allowed us to differentiate between the three groups of countries according to management processes. The first focused mostly on support strategies (support > planning > operation and evaluation) and included Bolivia and Chile. The second group included Argentina, Colombia, Paraguay, and Peru, which were balanced between planning and support strategies, but neglected operational and evaluation actions (support $\sim$ planning > operation and evaluation). The third group included only Ecuador and prioritized operation and evaluation strategies over support strategies; they also prioritized support strategies over planning strategies.

Referring to the center of the ternary diagram as the area that enables the existing harmony between all the management strategies to be seen, Paraguay was the most balanced country in the implementation of DRR management strategies (planning: 33%, support: 43%, and operation and evaluation: 23.33%). As shown in the correlation analysis (part B of Fig. 7), the geophysical factor was an important variable when explaining the implementation of DRR strategies. Since Paraguay was the only country that had not suffered geophysical extreme events during 2015–2019 and had medium R-MRI (see Table 1), it is not surprising that it was the most balanced country and that high-risk countries, such

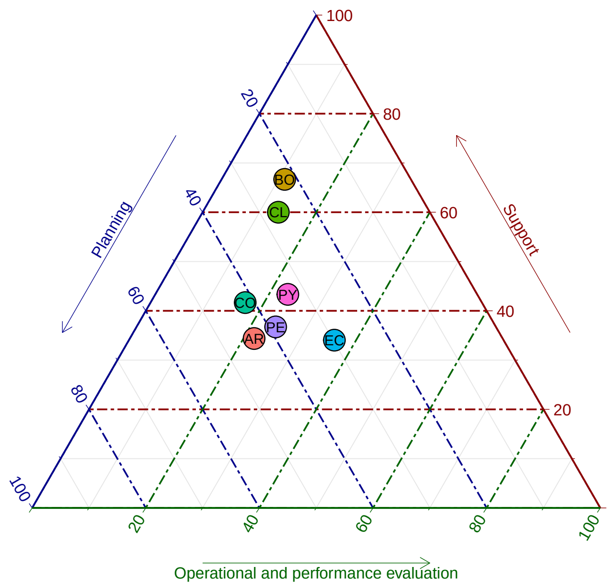

Fig. 9. Share of DRR strategies based on risk management categorization.

as Peru or Ecuador, were unbalanced (high R-MRI in Table 1).

5.3. Selective coding

The means of the absolute values of the correlations of the 16 indicators shown in Table 1 and Table 2 were contrasted against the priorities of the Sendai framework and the classification chosen by the HCA. By comparing parts A and B of Fig. 10, it was observed that the proposed classification by cluster represented better mean absolute correlations. Although C3 (Fig. 10A) was 0.26 overall, the sum of the four mean absolute correlations of the HCA classification (1.32) was greater than those of the four priorities of the Sendai framework (1.24).

Fig. 10C shows the correlations > 0.50 between the four priorities of SFDRR and the four clusters obtained by the HCA for the seven countries in this study. This analysis showed that all the SFDRR priorities were mostly correlated with planning of strengthening and articulation of actors (C3) and thereafter, to risk management, knowledge, and communication (C2).

In addition, priority four (P4) on disaster preparedness for response correlated with disaster management planning (C1).

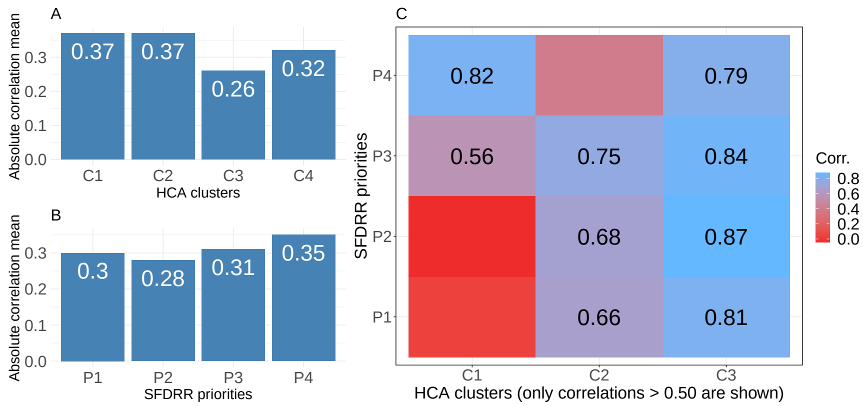

Fig. 10. Absolute correlation means of the 16 indicators displayed in Table 1 and Table 2 computed to HCA clusters (part A) and SFDRR priorities (part B). Part C shows the correlations between HCA clusters and SFDRR priorities. C1: Disaster management planning; C2: Risk management, knowledge, and communication; C3: Planning of strengthening and articulation of actors; C4: Risk governance planning.

One of the disadvantages of the categorization conducted using the SFDRR is the overlap of these categories. Therefore, since the exposed HCA classification did not overlap and better represented the mean absolute correlations, the 16 indicators exposed in Table 1 and Table 2 were correlated with the four clusters obtained by the HCA. This result is shown in Fig. 11 for indicators with correlations > 0.50.

Although part B of Fig. 7 shows, at a general level, that the DRR strategies correlated > 0.50 only with the indicators related to an extreme event, Fig. 11 shows that disaggregating the DRR strategies increases the correlations of the remaining indicators. Consequently, Fig. 11 demonstrates the importance of having a solid DRR strategy classification framework if one wants to understand beyond the triggering factor of the disaster. Thus, political stability (measured by the average of the presidential term) and the prosperity of the nation (measured by GDP per capita) are determining factors in the development of DRR strategies. This was especially the case for risk governance planning (C4) which was the central axis of the region (found through correlating strategies and countries in MCA exposed in Fig. 6). Clusters C2 and C3 had similar behaviors since they correlated positively with the metrics total population and R-MRI.

Comparatively, the correlations of the indicators against the disaster management planning cluster (C1) suggest that this type of strategy is generally implemented at the disaster and post-disaster level. This observation was made because the correlations of C1 were higher with the indicators related to the number of fatalities and geophysical events and were opposite to presidential stability.

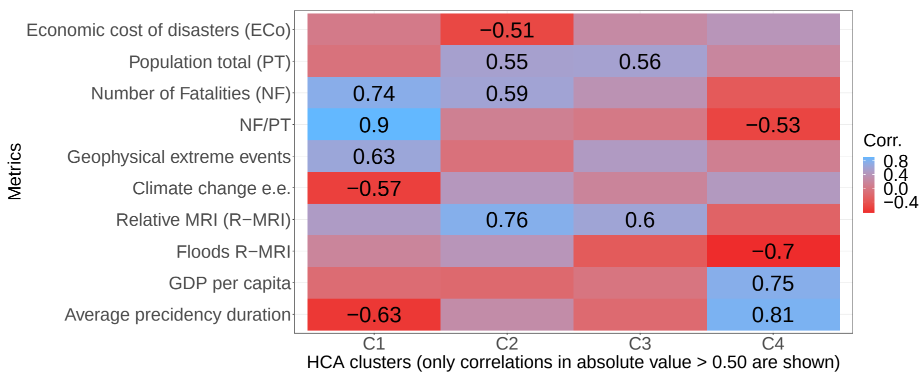

Fig. 11. Correlation matrix between the metrics exposed in Table 1 and Table 2 with the HCA clusters. C1: Disaster management planning; C2: Risk management, knowledge and communication; C3: Planning of strengthening and articulation of actors; C4: Risk governance planning.

5.4. Disaster risk reduction strategies literature review analysis in Spanish-speaking countries of South America

This subsection presents a literature review on general considerations, advances, and limitations of the DRR strategies in the seven sscSA. For the effects, the definitions provided in Table 6 and Table 7 were considered and the scientific information service Web of Science was used. It is important to note that this study was limited to reviewing only one element of the total range offered by the definitions provided since addressing the research of all DRR components was not the objective of this study.

5.4.1. Disaster management planning

C1 pertains to public health, safety, and welfare policies as a means of rebuilding healthier and more equitable societies after a disaster [66]. In this context, it is important to recognize the importance of strengthening prehospital capacity and intensive therapy to care for those affected prior to a disaster [67]. This should be done in addition to ensuring access to medicines to achieve the right to health (a constant problem in emerging countries) [68] and promoting the management of dialogue with influential groups that oppose the rights of the most vulnerable groups, such as the autonomy of women in the use of contraceptives [66].

To achieve greater reach and increase the impact of DRR strategies, it is important to use comprehensive, participatory, and inclusive approaches that are aimed at community-based strategies [69]. For this reason, it is necessary to conduct studies and previous diagnoses on social disparities and vulnerabilities [70]. Among other things, the socioeconomic sectors most affected should be considered according to the degree of the effect of the disaster that occurs [71, 72, 69]. In addition to the inclusion of vulnerable groups, such as ethnic groups [27], for people with chronic diseases, such as cancer and the human immunodeficiency virus [70, 68] who do not have social security but require attention [66] as well as pregnant women [66], finances play a central role.

Therefore, studies focused on generating reliable and transparent processes for managing public funds are required [73]. This is in addition to managing the imbalance in the allocation of financial resources between metropolitan regions and smaller municipalities that limit public participation and generate non-community approaches [69].

5.4.2. Risk management, knowledge and communication

Most risk mitigation and control strategies in the sscSA are triggered by emergencies (disaster and post-disaster action) and not under a risk prevention scenario [44]. Therefore, in Ecuador, the preservation of heritage areas has gained interest since the earthquake of April 16, 2016 [72]. In addition, the use of management techniques and monitoring of the deformation of the ground has gained importance because of the collapse of buildings generated by unauthorized excavations carried out underground [74]. However, agriculture is the main source of income in many rural regions of the sscSA (19% of the population of Latin America [38]). Therefore, the natural extremes that most affect this strategic sector are floods caused by events, such as the El Niño phenomenon [75]. The importance of the agricultural sector requires that the vulnerability of this sector be comprehensively evaluated and that social, economic, environmental, physical, and territorial elements are considered [76]. For example, at the community level, the risk associated with the handling of pesticides to household health is concerning [77].

Risk knowledge management plays an important role in the production of DRR solutions [78]. A knowledge management "solution," among other things, must include the knowledge management system and support for training and promotion of cultural change [78]. However, like other elements of DRR management, it is subject to risks, such as strategic and operational risk [78]. However, communication is a cross-cutting element of the DRR process that facilitates information flow between the different actors so that people continue their work, maintain their livelihoods in relative safety, and benefit from the assistance provided [79]. In this context, communication is emphasized as a means to reconstruct and mitigate against mental health risks in those affected. For example, in Chile after the earthquake on February 27, 2010, a planned, directed, structured and systematic process was fostered at four levels: Level 1: mass communication, Level 2: actions to protect mental health, Level 3: primary care, and Level 4: specialized clinical treatment [80].

5.4.3. Planning of strengthening and articulation of actors

Strengthening the response and articulation of actors in the sscSA is a very complex issue due to the limited monetary or technological capacity of some countries [81]. Thus, risk assessment processes are often hampered by a lack of adequate records, data, and estimates associated with the high cost and time-consuming nature of preparing these measurements [42, 43, 44].

In the field of disaster preparedness, the Coronavirus Disease (COVID-19) pandemic and the failures of health equipment and infrastructure increased the risk of contagion of doctors and patients in the Latin American health system during 2020 [82].

Regarding the articulation of actors, it is necessary not only to form crisis committees [82, 83], but also for community centers to actively participate in understanding the resilience of people in the face of risk and their actions in favor of DRR policies [5, 42].

However, the transfer of disaster risk through insurance policies must overcome several barriers to achieve the commitment of insurance companies [75]. For example, the insurance of the agricultural sector is limited by problems of detecting areas of high climatic risk, control of false information on crop yield, administrative costs associated with loss verification and program administration, and managing the rapid payment of benefits to policyholders after a catastrophe [75].

5.4.4. Risk governance planning

South American countries share an interest in the early detection of extreme events related to water and rain [84, 85, 86, 87, 88]. However, this results in a lack of applications to generate information on environmental conditions [86]. In this sense, it is important to take advantage of opportunities at hand. For example, Argentina uses information on rainfall variability to detect extreme water events [84]. To further illustrate, Chile studies the concentration of sediments in the propagation of flash floods in watersheds [88], Colombia has spatial and temporal data for the early detection of mass movements [87], Ecuador uses alternative information sources, such as complaints from people, media photographs, and watermarks on the walls [85], and Peru plans to install a debris flow type mass movement detection system and temporary dams with activation cables, geophones, and water level measurements [86].

Regarding the exchange of experiences between actors, the role of NGOs, such as the Pan American Health Organization, is highlighted [89]. In the context of the sscSA, this NGO not only favors the exchange of experiences but also the development of training and workshops, technical cooperation in patient management and epidemiological, entomological, laboratory and epizootic surveillance, organization of the assistance network, and acquisition of strategic supplies [89].

Two-way communication and intervention is an instrument that seeks to promote social development and inclusion in disadvantaged sectors by increasing access to knowledge, resources, or public services [90]. In the Ecuadorian context, the "Share for Care" system is prominent in supporting community and collaborative work of the population through Information and Communication Technologies [90].

Finally, the generation of participatory processes within the community has gained strength in recent years [91]. These bottom-up adaptation strategies seek to build stronger and potentially more stable community networks in socially unstable territories [91]. In this context, Colombia is a country that has implemented a participatory social network for monitoring floods, torrential floods, and landslides in 80 municipalities [91].

6. Conclusions

DRR plans in the sscSA were found to be highly aligned with the SFDRR, especially with priority one related to disaster risk understanding. This finding is consistent with that of Lassa et al. [16], but inconsistent with the conclusions of previous studies about other regions, such as in the African context where the literature indicates that risk management systems do not conform to contemporary international frameworks, such as the SFDRR [17].

The combination of CAQDAS with the HCA enabled the classification of the DRR strategies of the sscSA into four clusters. The correlation of these four clusters with 16 indicators related to the cause of disasters made it possible to visualize important relationships that facilitate the understanding of the implementation of these strategies (see Fig. 11). Among them, the importance of governments' stability to implement risk governance planning strategies (C4) was highlighted. In addition, the positive correlation of disaster management planning strategies (C1) with indicators related to the impact of disasters suggests that these kinds of strategies are implemented after a disaster hits. Moreover, the interaction of DRR strategies in the sscSA was analyzed using an MCA which allowed us to differentiate between four groups of management planning of DRR strategies. The first group was associated with "planning based on social participation and stakeholder management." Most analyzed countries were identified with this group, that is, Bolivia, Chile, Paraguay, Argentina, and Peru. According to the literature, this is in line with the people-centered risk strategy [36]. In this regard, if management is only based on these strategies, the impact of DRR will depend on people's sensitivity to a disaster since it is they who access, learn, implement, communicate, and cooperate [36].

The second planning type, which Ecuador has employed, was based on preparing for a crisis response. A management approach of this type is characteristic in certain countries of the world, such as Sweden or Poland, where risk management is oriented toward the emergency response phase of the disaster cycle [15]. Like these authors, we agree that relying only on this type of management limits comprehensive risk management since it neglects other areas, such as generating knowledge of risk or preventing risks. Hence, this group of strategies must be considered a complementary element to the other three forms of planning.

The third component was related to "post-disaster continuity management planning." In our study, no country identified itself with this component, so this type of strategy planning is minimal in this region. This is often attributed to a lack of communication with local communities and businesses in the pre-disaster period, including a lack of implementation of disaster solutions by individuals and small businesses [20]. In the regional context, we found evidence that suggests that investment in disaster management as a DRR mechanism is usually considered an expense (a particular case of Bolivia) and not as a form of resilience investment [27].

The fourth component of risk was associated with the "management planning of essential sectors continuity." This component begins with the knowledge, strengthening, and comprehensive risk management of essential sectors, such as water, electricity, telephone, medical, and heritage areas. These types of strategies, with which Colombia was represented, are associated with the concept of resilience. We consider this management type to be the most challenging as the vulnerability component of disaster risk must be addressed. However, by addressing this component, changes can be effectively implemented [92].

Additionally, observing the relation between these four pillars of DRR in the MCA biplot, it is concluded that the countries that planned for risk based on "social participation and stakeholder management" generally neglected post-disaster continuity strategies. Furthermore, countries that planned based on preparing for a crisis response neglected the component on "continuity of strategic sectors" and vice versa.

The existing literature suggests that almost all response and post-disaster strategies in sscSA are triggered by emergencies and not by a risk prevention scenario [44]. In this study, it is justified that prevention strategies are contrasted with those of response and post-disaster since most countries were associated with strategies related to the prevention phase and, to a lesser extent, with strategies for disaster and post-disaster.

Comparatively, the dichotomy between strategies on prevention and disaster recovery has been discussed by several authors [93]. This thematic characterization was also addressed in this study and we provide evidence that in situations before a disaster, most countries focus on preventive strategies over corrective ones. It was also found that countries tend to focus more on recovery strategies after a crisis event has occurred, such as Ecuador, which suffered an earthquake in 2016.

The MCA allowed us to find some relationships between the thematic codes based on the SFDRR and management process categories and action type (both based on the ISO 9001:2015 standards). A close relationship between the concept of corrective actions and operational management with priority four of disaster preparedness for response, planning action and investment in risk reduction strategies (P3 of the SFDRR) as well as support and preventive actions with strengthening of risk governance strategies (priority two) and disaster risk understanding (priority one) was found.

Therefore, we suggest that the risk management approach based on quality ISO 9001:2015 standards can provide a solid foundation to classify risk reduction strategies that strengthen DRR thinking as a joint and unified system and not as individual structures for risk management.

Finally, the methodology presented here was used to analyze the DRR strategies in the particular case of seven sscSA. Consequently, an overview of the DRR strategies implemented was provided and can be used to make comparisons on DRR planning at the regional level. Furthermore, this study could be easily replicated to analyze other regions of the world; however, it has highlighted a need for DRR plans where the DRR strategies are detailed, a theoretical approach to analyze these strategies utilized, and a text mining method, such as the proposed one.

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