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A Community Disaster Resilience Index for Chile

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Abstract: Although Chile is one of the countries most exposed to natural hazards, to date there is no national index that shows the differences in resilience levels within the country. This study develops a community resilience index on a national scale based on the Baseline Resilience Community (BRIC) index. The BRIC index for Chile was built with 49 indicators, from different sources at the district level. Our results determined that resilience is not distributed homogeneously throughout the country. The highest levels of resilience are concentrated in the central macro-zone. In comparison, the extreme zones of Chile focus close to 90% of their population in the lowest levels, accounting for an uneven distribution of resources and services that impact resilience levels. These differences were mainly explained by indicators such as the percentage of the population without a health insurance system, the percentage of the population without internet access, and the percentage of electoral participation, among others. The results demonstrate that the BRIC model can be successfully implemented to assess community resilience in Chile and suggests the possibility of targeting resources and strategies to increase resilience in areas with the lowest levels of community resilience.

Keywords: resilience; community; BRIC; Chile

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1. Introduction

In the last two decades, earthquakes and tsunamis have generated the most significant number of human and economic losses, causing 1.3 million deaths. Climate-change-related events also represent 91% of the disasters that occurred in the past year [1]. This accounts for the growing impact of disasters on communities.

Several institutions and scientific associations have made progress in understanding hazards and their potential effects on the environment and communities. These studies have sought to reduce territories' exposure and vulnerability by developing risk mitigation strategies. However, over the last decade, the risk-management action frameworks and the sustainable development goals have highlighted that reducing disaster risk also requires building more resilient communities [2].

Defining resilience can be a significant challenge since its conceptualization varies depending on the discipline that is studying it and the unit of analysis considered: from individuals to communities and territories [3]. Although there is still no consensus on its definition, some of the most used conceptualizations for resilience understand it as the capacity of systems to absorb and respond to disaster impacts [4]. On the other hand, the Sendai Framework for Disaster Risk Reduction and other international initiatives propose that resilience is an individual's or a community's ability to face the impact of natural disasters and to anticipate, recover, and adapt to them to maintain their identity and everyday functioning [2,5].

Different dimensions of resilience emerge from its multiple definitions and units of analysis. Although most studies have focused on understanding the resilience of physical systems, such as critical infrastructure [3,6], progress has also been made in our understanding of individual resilience, as the fundamental psychosocial conditions required to avoid the potentially traumatic impact of an event [7].

During the last decades, the study of community resilience has become more relevant. The aim is to identify the capacities and processes that communities live with [7] and develop to face a potentially catastrophic event [8,9]. Various approaches have advanced the understanding of community resilience, providing a theoretical basis for its measurement. Each approach follows different definitions of resilience, either as a pre-existing capacity in communities or as part of a process that integrates the resources that communities have available to anticipate, prevent and adapt to a disaster [10,11]. These approaches include the Socio-Ecological Perspective [12], the Framework of Sustainability [13], the Disaster Resilience Integrated Framework for Transformation (DRIFT) [11], and the Disaster Resilience of Place (DROP) model [6]. The latter understands community resilience as the inherent capacities that allow a system to absorb the impact of disasters, generating a specific response and recovery time in the face of these events [6,14].

Unlike other models, the DROP model has managed to integrate the main dimensions of resilience to natural disasters discussed in the literature. This model was designed for natural disasters with immediate effects, such as earthquakes or tsunamis, and hazards with slower impacts, such as events related to climate change.

In the DROP model, resilience is related to social vulnerability. In this approach, social vulnerability and resilience are characteristics inherent to territories that are related but different from each other [6,15]. A territory can, therefore, be highly vulnerable but not necessarily less resilient since it can have capacities—such as social capital—that allow it to adapt better after an event [16,17].

From the DROP model, Cutter et al. [18] have developed the Baseline Resilience Index for Communities (BRIC), which seeks to create a replicable metric that integrates different types of resilience. The BRIC considers the community as the fundamental unit of analysis, i.e., those interpersonal interactions that occur in a geographical location [18]. This index incorporates indicators that reflect six dimensions of resilience: social resilience, community capital, economic resilience, institutional resilience, infrastructure resilience, and environmental resilience. It should be noted that this index is part of a top-down approach where the indicators to measure resilience are chosen by researchers based on a literature review or expert judgment.

Given its multidimensional nature and relative ease of replication, the BRIC has been used to measure community resilience in several countries, mainly focusing on specific regions, states, or municipalities [10]. Only some studies, however, have estimated the BRIC at the national level. The first nationwide BRIC was carried out by Cutter et al. [18] in the US. The authors found the lowest resilient levels to be concentrated in the Midwest. Conversely, the highest resilience indices were clustered in the western and southern parts of the United States. They also found that most resilient counties had the highest levels of investment in mitigation measures or were closest to metropolitan areas.

In addition to the original study in [18] carried out in the United States, [19] is a study conducted in Norway. The authors considered the six dimensions of resilience integrated into the BRIC proposed by Cutter et al. [18], adapting the variables to the availability of data and the country's context and validating the process by a team of experts through focus groups. They also calculated sub-indices for each dimension of resilience to observe the distribution of economic, social, institutional, environmental, and infrastructure resilience throughout the different municipalities of Norway. Using this metric, the authors found high variability in the levels of resilience throughout the territory, with large cities showing the highest levels of resilience. These results are similar to those of previous studies where it was found that urban territories constitute concentrations of the high levels of resilience due to the topography of the place. In contrast, flatter places, such as large cities, have characteristics that favor economic and social development [20].

Integrating the community resilience approach to develop disaster risk reduction plans, programs, and policies becomes relevant given the current scenario of a significant global increase in socio-natural disasters. Due to its location in the Pacific Ring of Fire, Chile is one of the countries with a higher risk of multiple natural hazards [21]. Between 1980 and 2011, Chile registered an average of losses approaching 1.2% of its GDP due to socio-natural disasters [2,5]. Hence, creating a more resilient country is essential to reducing the impact of future disasters.

Numerous studies have contributed to characterizing resilience in Chile, mainly evaluating the resilience of critical infrastructure against natural hazards [22,23]. Researchers have also sought to incorporate different community and institutional perspectives defining resilience [24,25]. Although significant progress has been made in understanding the dimensions that characterize resilience for communities and territories, Chile still lacks a nationwide community resilience index that can be applied to multi-hazard scenarios. To bridge this gap, this study's main objective is to develop a community resilience index for Chile based on the BRIC index. Having a national community resilience index would allow the identification of the territories with the country's lowest (or highest) levels of resilience and more efficient allocation of resources.

Finally, through the development of the BRIC index, we will be able to observe which indicators of social, economic, and environmental development impact the country's capacity to respond to natural disasters. This first approximation of the levels of resilience allows us to provide a tool to achieve the sustainable development goals that seek to reduce inequality within countries, reduce vulnerability to disasters and generate more resilient communities. In addition, this indicator can be a baseline to evaluate the impact of strategies and programs that promote community resilience for different localities.

1.1. Resilience Categories

The BRIC index incorporates six resilience dimensions representing the large systems involved in communities' response and recovery processes in the face of natural disasters.

1.1.1. Social Resilience

This dimension focuses on the capacities of social groups to face disaster effectively, being able to return to how they functioned before the event [26,27]. It is characterized by three processes or elements that manifest themselves in the community when facing a disaster: that any social group has resistance to face the consequences, that it can recover in a short period, and that it can also adapt to new circumstances [28–30].

The diversity of people within a community result in the emergence of groups with higher or lower levels of resilience. Previous studies have identified that, in general, older adults have more difficulties coping with disasters, which may affect their resilience capacity [27,28,31]. In addition, both studies that applied the BRIC at the national level found that not having the ability to purchase a car or having lower access to medical services resulted in lower levels of resilience in the areas under study.

Social resilience has been measured depending on the unit being studied (communities, families, etc.) and their capacities to cope (planning, human and economic resources, among others) [32,33]. In the DROP model, the social-resilience measure includes the demographic qualities of the community and its ability to maintain its well-being when facing a disaster [6,18].

1.1.2. Community Capital

Community's resources are essential to determining its disaster response. Social capital considers the interpersonal networks within a social group. It integrates the links between the family, neighborhoods, social organizations, and community members and the figures or centers of power [26,34].

People's contact networks are crucial in emergencies and disasters. They improve disaster response and function as facilitators to make people aware of preparedness measures [35]. These actions are strengthened when people become attached to their places of residence, share a feeling of belonging, and participate in citizen organizations [36]. For example, the migrant population is part of the most vulnerable groups because they do not have support networks that will allow them to face a disaster. Cutter et al. [18] found that counties with moderate levels of community capital were those with the lowest percentage of the migrant population.

Social capital and its multiple elements are considered part of social resilience. The BRIC model, however, quantifies it as a dimension, since it seeks to look beyond interpersonal networks and allows us to capture how people become involved in the community [6]. In this way, variables associated with attachment to place (measured in years of residence in the country), people born in other countries, and participation in civil or humanitarian aid organizations are included [18].

1.1.3. Economic Resilience

This dimension is defined as the community's and economic systems' capacity to mitigate the impact of socio-natural disasters [37,38]. This approach considers that socio-natural disasters have both a macroeconomic and a microeconomic effect, recognizing the impact on a countries' productive systems, businesses, and households [39,40].

Territories with better economic conditions have better disaster planning and mitigation resources, enabling their communities to recover more quickly from disasters and rapidly generate more resilient communities [41]. In addition, previous studies found that having a higher percentage of people working resulted in higher levels of resilience in counties or districts. Similarly, this was the case for areas whose economies were less dependent on the primary sector. Although most technical studies of economic resilience use mathematical models to understand recovery trajectories, in a resilience index, the focus is on establishing an economic profile of the study area. In general, the indicators used measure the diversity of the economic sectors on which communities depend, the equitable distribution of resources, and other variables that represent the state of local businesses [6].

1.1.4. Institutional Resilience

The organizations and institutions that manage risk are crucial to increasing a community's resilience. Institutional resilience is the capacity of organizations to respond and continue to function after a crisis [42,43]. The main characteristics of a resilient organization or institution include collaborative work, managing vulnerability, and adaptability [44,45].

Previous studies investigating the post-disaster scenario reported that institutions that are not coordinated or have poor communication hamper the response to disasters, reducing the community's capacity to face and absorb disaster impacts [46]. Additionally, the more institutions invest in mitigation measures or insurance to face disasters, the higher the levels of resilience are.

Government institutions' disaster-response resources and their organization or planning strategies are considered when measuring institutional resilience [42]. In the BRIC index, institutional resilience includes variables related to government coordination and how centralized institutional resources, which are sources of political or economic power, are. Variables represent the state programs delivered to the community to facilitate recovery and the human resources trained to respond to natural disasters [6,14].

1.1.5. Infrastructure Resilience

This dimension of resilience focuses on the physical capacities of the critical infrastructure that allow the community to continue functioning after a disaster, including water and electricity-supply services, communication services, education, and health, among others [47]. Infrastructure is resilient when it is robust and can quickly return to operation, so that disaster impacts do not affect the population in the long term [42].

A lack of resilient infrastructure hinders a community's functioning and can also increase the human and economic losses from a disaster. Previous research has identified that during Hurricane Katrina in New Orleans, one of the impacts faced by the affected territories was the loss of essential services, which increased the time it took them to recover [48,49].

Although different approaches can be used to study infrastructure resilience, within the BRIC index this dimension integrates indicators representing the quality of housing, the physical capacity of medical and educational services, and the resources that facilitate evacuation processes (evacuation routes and shelters) [18].

1.1.6. Environmental Resilience

Environmental resilience refers to the ability of ecological systems to absorb the impact of a disruptive event, which enables natural systems to recover their current processes or change by adapting to new circumstances [50]. The main characteristics that favor environmental resilience include species diversity and diversity in the functions of the different natural systems, in addition to the balance established between natural and social systems concerning the efficiency of natural resource use [51].

Previous research has shown that extensive deforestation or ecosystem destruction increases the risk of floods and their impact, hindering the recovery of territories [52]. In addition, Cutter et al. [18] found that districts with lower levels of environmental resilience were those with greater water scarcity. On the contrary, districts with higher resilience were those that had ecosystem protection, such as wetlands.

The environmental-resilience dimension is, therefore, composed of indicators representing territories' exposure to different natural hazards, the natural resources that allow impact mitigation (such as wetlands or dunes), and the sustainability of natural resources [12,14].

2. Materials and Methods

2.1. Study Area

Chile is a South American country with more than 6400 km^2 of coastline [53] which currently houses 17.5 million inhabitants, 51.5% of whom are women (Figure 1). According to the last census records, Chile is in an advanced stage of population aging, with a fertility rate of 1.6 and an aging index of 63.1 [54].

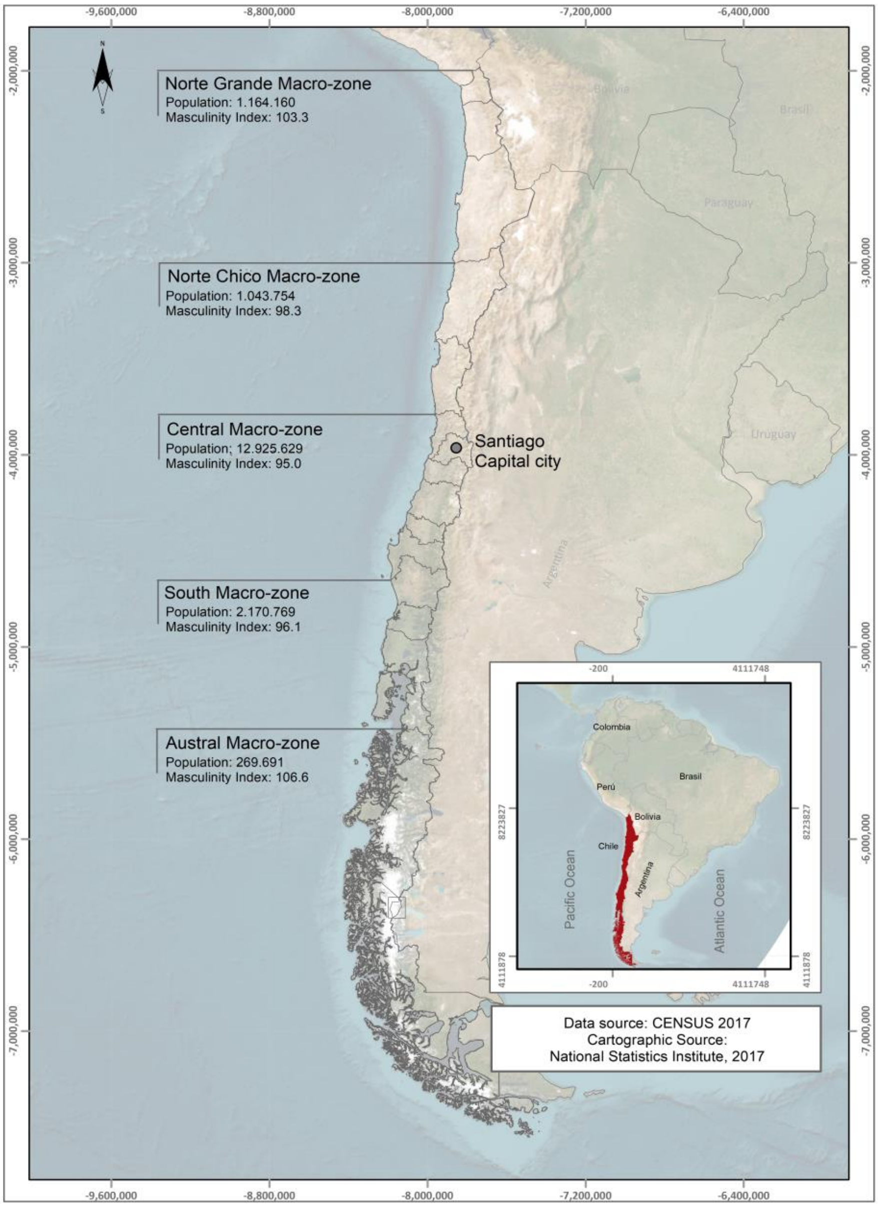

Figure 1. Spatial context. Source: prepared by the authors based on census data (INE, 2017) [55].

Chile is divided politically and administratively into 16 regions, 56 provinces, 346 communes, and 3100 districts [53]. Due to their geographical extension, and geographic diversity, the country's regions and districts are grouped into five macro-zones: Norte Grande, Norte Chico, Central, South, and Austral, as depicted in Figure 1 [56].

The Norte Grande and Norte Chico macro-zones are the least populated in the country, housing 13% of the national population with a high migrant population (the migrant population of the Norte Grande and Norte Chico macro-zones is characterized by being mostly women, young people between 25 and 36 years old, and coming from countries such as Peru, Bolivia, Venezuela, and Colombia. In turn, 50% of the migrant population is characterized by having arrived in the country during the period 2010–2017. The schooling of approximately 30% of migrants reaches the professional level, with more than four years of higher education [55,57]) (20% of the total foreign population residing in Chile) [57]. Both macro-zones have an arid or semi-arid climate and house the Atacama Desert, the driest desert on the planet. The main economic activity in Chile is mining, which is concentrated mainly in these two macro-zones [58].

More than ten million inhabitants live in the Central macro-zone, nearly 70% of the national population. Around 65% of the country's migrant population lives in this macro-zone, mainly in the capital of Chile, Santiago (INE, 2017, 2022). This macro-zone is characterized by its housing of the three State powers: executive, legislative, and judicial [55,59]. The Central macro-zone has a Mediterranean and rainy climate, allowing its main economic activity to be agriculture and port activity.

Finally, the South and Austral macrozones are part of the south and extreme south of the country, hosting approximately 14% of the national population [55]. In these macro-zones, the climate is rainy, humid, and with low temperatures [53]; it hosts the natural areas with the most significant number of nature reserves and national parks in the country, which exceed 10 million hectares [60]. The main economic activities of these macrozones are aquaculture, forestry, and livestock.

2.2. Resilience Indicators

Based on previous studies, we selected 49 variables to construct the BRIC in Chile (Table 1). These were grouped conceptually and theoretically into the six dimensions of resilience established by [18]: Social Resilience, Community Capital, Economic Resilience, Institutional Resilience, Infrastructure Resilience, and Environmental Resilience.

Table 1. Summary statistics for the indicators included in the community resilience index.

Resilience Dimension	Initials	Source	Minimum	Maximum	Mean	SD
Social (N = 11; α = 0.404)						
% of two-parent households with children	S1	Census 2017 [1]	1.0	100.0	26.2	7.9
% of households with telephone service available	S2	CASEN 2017 [2]	64.0	94.0	85.0	3.9
% of households without food insecurity	S3	CASEN 2017	23.3	97.7	74.4	10.4
% of population affiliated to a pension fund	S4	CASEN 2017	31.0	88.9	65.4	9.0
% of population with a health insurance system	S5	CASEN 2017	80.0	100.0	95.1	2.8
% of population over 25 who reached basic ed.	S6	Census 2017 [1]	13.0	100.0	72.8	14.5
% of population that speaks Spanish	S7	Census 2017 [1]	0.0	100.0	72.2	22.2
% population under 65	S8	Census 2017 [1]	27.3	100.0	85.1	5.6
% population without disability	S9	CASEN 2017	77.2	98.0	91.0	3.3
Number of doctors per 10,000 inhab.	S10	SNSS, 2018 [3]	6.9	30.0	17.6	6.5
No. of psychologists per 10,000 inhabitants.	S11	SNSS, 2018	0.3	1.7	1.0	0.4
Social-Community Capital (N = 6; α = 0.438)						
% voter turnout	SC1	Servel 2017 [4]	1.0	100.0	26.2	7.9
% of population from another country with residence in 2012	SC2	Census 2017 [1]	64.0	94.0	85.0	3.9
% of population born in Chile	SC3	Census 2017 [1]	23.3	97.7	74.4	10.4
% of population participating in civil organizations	SC4	CASEN 2015	31.0	88.9	65.4	9.0
% of population participating in religious organizations	SC5	CASEN 2015	80.0	100.0	95.1	2.8
% of population participating in volunteering	SC6	CASEN 2015	13.0	100.0	72.8	14.5
Economic (N = 7; α = 0.510)						
% gap between both genders	E1	CASEN 2017	−22.0	70.0	11.5	10.1
% of home ownership	E2	CASEN 2017	22.5	97.0	74.8	8.1
Degree of employment diversification	E3	Census 2017 [1]	738.9	10,000	2083	1405.9
% population employed in non-resilient sectors	E4	Census 2017 [1]	0.0	100.0	28.2	18.6
% population working	E5	Census 2017 [1]	0.0	100.0	53.0	13.0
No. of trading companies	E6	SII 2019 [5]	1.0	186.0	22.5	32.4
Ratio between large and small companies	E7	IBS 2019	0.0	2.6	0.2	0.2

Table 1. *Cont.*

Resilience Dimension	Initials	Source	Minimum	Maximum	Mean	SD
Institutional (N = 7; α = −0.050)						
Km away from the regional capital	IT1	MINVU, 2017 [6]	176.2	3,575,439.6	62,171.1	117,588.7
Number of credits and subsidies for agricultural development	IT2	PASO 2019 [7]	0.0	492.0	31.9	44.1
No. of districts per region	IT3	BCN, 2017 [8]	37.0	451.0	251.7	113.6
Number of people trained by ONEMI	IT4	ONEMI, 2020 [9]	13.0	256.0	23.5	44.7
Number of agricultural insurance policies	IT5	INDAP 2019 [10]	0.0	3602.0	1293.4	1255.7
No. governorates	IT6	Barcelona, 2017	2.0	8.0	4.0	1.8
Intercensal growth rate 2015–2020	IT7	Census 2017 [1]	−1.5	7.9	1.1	1.1
Infrastructure (N = 8; α = 0.393)						
% of households with acceptable materiality	IF1	Census 2017 [1]	10.0	100.0	86.0	12.0
% population with internet access	IF2	CASEN 2017	0.0	93.0	26.0	19.0
% Homes built post. thermal standard	IF3	MINVU	0.0	61.3	25.2	9.8
Km railway network per km^2	IF4	Friends of the train [11]	0.0	4.1	0.1	0.2
Km road network per km^2	IF5	MOP, 2008 [12]	0.0	5.6	0.3	0.4
Distance to airports or aerodromes in km.	IF6	Barcelona, 2021	235.2	827,140.4	17,411.1	22,638.1
Number of educational centers per 10,000 inhabitants.	IF7	MINEDUC [13]	0.1	1428.6	11.5	37.5
No. of coastal protection works	IF8	CCCOSTAS, 2019 [14]	0.0	100.0	0.02	0.2
Environmental (N = 10; α = 0.086)						
% of biodiversity areas	A1	MMA, 2019 [15]	0.0	100.0	4.2	17.1
% soil without potential erosion	A2	CIREN, 2010 [16]	0.0	89.4	40.0	25.0
% of surface considered as wetlands	A3	MMA,2020	0.0	43.4	1.6	3.5
% of protected area (SNASPE)	A4	SNASPE, 2016 [17]	0.0	89.0	1.1	5.8
% of arable land	A5	CONAF, 2014 [18]	0.0	99.9	26.9	32.8
% area without land use change	A6	MINAGRI,2012–2019 [19]	0.0	100.0	98.5	6.3
Km of rivers per km^2	A7	Barcelona, 2019	0.0	3.3	0.1	0.2
Km^2 with water scarcity decrees	A8	DGA, 2020 [20]	0.0	40,583.3	6711.7	12,840.7
No. of dune fields	A9	CC Coasts, 2019	0.0	9.0	0.1	0.5
N° forest industries 10,000 inhab.	A10	Forest Institute, 2019	0.0	303.0	1.2	7.4

N: Number of indicators per resilience dimension; *α: Cronbach's Alpha of each resilience scale*; [1] CENSUS: Population and Housing Census; [2] CASEN: National Socioeconomic Characterization Survey (CASEN); [3] SNSS: National System of Health Services; [4] SERVEL: Electoral Service of Chile; [5] SII: Internal Revenue Service; [6] MINVU: Ministry of Housing and Urban Development; [7] ODEPA: Office of Agrarian Studies and Policies; [8] BCN: National Congress Library; [9] ONEMI: National Emergency Office of the Ministry of the Interior; [10] INDAP: Institute of Agricultural Development; [11] Friends of the Train: Private initiative for the dissemination and maintenance of railway infrastructure in Chile; [12] MOP: Ministry of Public Works; [13] MINEDUC: Ministry of Education; [14] CCCOSTAS: Determination of the risk of the impacts of Climate Change on the coasts of Chile, Environment Ministries Initiative; [15] MMA: Ministry of the Environment; [16] CIREN: Natural Resources Information Center; [17] SNASPE: National System of Protected Wilderness Areas of the State; [18] CONAF: National Forestry Corporation; [19] MINAGRI: Ministry of Agriculture, [20] DGA: General Directorate of Water.

Eleven indicators were selected for measuring social resilience, which takes into account the demographic characteristics and socioeconomic conditions of households. These indicators include factors such as educational attainment [18], the number of doctors [26] and psychologists per thousand inhabitants [19], and the percentage of the population affiliated with health insurance and pension funds [18]. These indicators reflect the characteristics and capabilities that enable individuals and communities to be better equipped to deal with disasters and recover more effectively. The Community-Capital dimension includes six indicators that represent community participation in various civic and social activities, such as electoral participation [13], and participation in religious or volunteer organizations [18]. It also includes indicators associated with attachment and belonging to the place, such as years of residence and population born in the country [26].

The Economic-Resilience dimension comprises seven indicators that measure the macroeconomic and microeconomic characteristics affected by disasters. It is understood that better economic systems create better conditions for communities to cope with and recover from disasters [38,39]. The selected indicators include those that represent the economic sectors of the country, such as the ratio between large and small companies [14,37] and the degree of employment diversification, as well as indicators that reflect the income equality between men and women [18] and the percentage of the employed population [14]. Seven Institutional-Resilience indicators were selected to reflect the level of decentralization of state powers and the institutional capacity of the country to cope with and recover from disasters. These indicators include the number of governorates and districts per region [18], the number of professionals trained in disaster management [18], as well as the level of subsidies and insurance for agricultural development.

Infrastructure Resilience includes eight indicators aimed at measuring the capacity of critical infrastructure, on which the continuous functioning of communities depend after a disaster [47]. The presence of essential services in localities, such as transportation networks [6] and access to internet services [18], were considered, as well as the quality of housing [18,42]. Finally, ten indicators were included in the Environmental-Resilience dimension to characterize the abundant diversity of natural resources in different geographical areas of the country. The selected indicators include those that measure the current state of soils [19] and indicators that represent fragile ecosystems such as dune fields and wetlands [43].

2.3. Data

All variables were obtained through public and private databases (Table 1). A total of 11 variables were from the 2017 Population and Housing Census conducted by the National Institute of Statistics of Chile (INE). The second source of information corresponds to the National Socioeconomic Characterization Survey (CASEN) for the years 2015 and 2017, which characterizes the socioeconomic situation of households in the country, including housing, health, education, and income. We chose eleven variables from this survey.

We obtained the remaining variables (N = 27) through a transparency request to different ministries and services of Chile. Most of the variables represent data from 2015–2020; only the variable road network per km^2 (IF5 in Table 1) is from 2008, which is the last update date for this indicator.

The variables and the BRIC index were calculated and represented at the district level, corresponding to the smallest operational unit used by the Population and Housing Census to represent data. The districts correspond to zones and localities depicting the country's urban and rural units, respectively [61].

2.4. Data Analysis

To construct the BRIC resilience index for Chile, we followed the methodology proposed by [18]. First, the 49 variables were transformed into percentages and averages, depending on their nature. We excluded variables that required a spatial analysis (IT1, IF4, IF5, IF6, A7, and A8 in Table 1). The entire set of variables was then normalized using a scale between 0 and 1. A positive relationship with resilience was considered for all variables, transforming the variables with inverse interpretation (indicators S6, E1, E4, IF6, SC2, IT1, A8 and A10 in Table 1).

The scale's reliability was analyzed using Cronbach's alpha test for the complete set of variables and each dimension of resilience. For the former, we obtained a moderate value (α = 0.58), suggesting an acceptable level of reliability. For the resilience dimensions, moderate-to-low values were obtained (Table 2), similar to those found in previous studies [18,19]. Obtaining moderate, low, and negative values of reliability can be explained by the methodological design followed in this study. We assigned the different indicators to each dimension following a theoretical review of one mathematical distribution. Consequently, as mentioned by Cutter et al. [18], individual dimensions of resilience are not expected to exhibit reliable or high Cronbach's-alpha values since it only seeks to know the level of composition of the dimensions.

Table 2. Cronbach's alpha results for indicators within each resilience category.

Resilience Dimensions	Number of Indicators	Cronbach's Alpha
Social	11	0.404
Social capital	6	0.438
Economic	7	0.510 +
Institutional	7	−0.05
Infrastructure	8	0.393 +
Environmental	10	0.086

Each variable was added to the corresponding resilience dimension to then calculate each dimension's average. A minimum–maximum transformation was developed considering a minimum value of 0 and a maximum value of 1. Once the subindex of each resilience dimension was calculated, these were summed up to obtain the BRIC score on a scale from 0 to 6. Five levels of resilience were considered from standard-deviation (SD) ranges for resilience zoning. Thus, districts with very low resilience were those with values lower than −1.5 SD; low resilience with values between −1.5 to −0.5 SD; medium resilience between −0.5 and 0.5 SD; high resilience with values between 0.5 and 1.5 SD; and values greater than 1.5 SD were defined as very high resilience.

Then, a bivariate correlation was performed between the resilience sub-indices and the total BRIC score (Table 3) to observe whether the resilience sub-indices explain different dimensions of community resilience.

Table 3. Correlations between the resilience dimensions.

	Social	Social Capital	Economic	Institutional	Infrastructure	Environmental	BRICS
Social	1000						
Social capital	0.312 **	1000					
Economic	−0.058 **	−0.158 **	1000				
Institutional	0.362 **	0.197 **	−0.030	1000			
Infrastructure	0.358 **	0.551 **	−0.016	0.295 **	1000		
Environmental	0.089 **	0.118 **	0.150 **	0.145 **	0.237 **	1000	
BRICS	0.672 **	0.591 **	0.184 **	0.679 **	0.693 **	0.478 **	1000

Note: ** significant correlation at the 0.01 level (bilateral).

A principal component analysis (PCA) was conducted using six factors to explore if the variables and dimensions of the resilience group are similar to the six types of community resilience used for the BRIC. The PCA showed a different grouping from that previously established in the literature, explaining 37% of the variance in resilience. Although this value is considered low, it is similar to that obtained in previous studies, such as in the United States, where the PCA analysis obtained a variance of 39.4% for the same number of factors [18]. In this sense, the six factors obtained were: (1) accessibility to communication, health, social security services, and social characteristics; (2) occupation and institutionally; (3) participation in organizations and housing materiality; (4) commerce and governance; (5) electoral participation and homeownership; and (6) resident population. Once the PCA was performed, the value of each factor was added and correlated with the BRIC index, obtaining a significant correlation of 0.75 ($p < 0.001$), suggesting that even with another distribution, the variables have the explanatory power to account for resilience.

Finally, a spatial autocorrelation analysis was performed using the global Moran and the local Moran's index (LISA) to observe the country's resilience-levels distribution. The first analysis allows us to examine whether resilience is distributed uniformly throughout space. The LISA index will enable comparisons between each district with the global average and neighboring districts by grouping them into clusters [62]. Districts with a similar value to their adjacent units are grouped into a high–high cluster if their value is higher than the average and a low–low cluster if the values are lower than the global average of resilience. On the other hand, districts with different mean values to neighboring units belong to the high–low or low–high cluster according to their mean [63].

3. Results

3.1. National BRIC Index

We obtained the resilience analysis for 3100 districts distributed throughout the national territory. As seen in Table 4, the BRIC for Chile scale has an average value of 3.21 (SD = 0.50). The results show that about 30% of the Chilean population lives in districts with a low or very low level of community resilience.

Table 4. Average values of the BRIC index and proportion of the population by level of resilience for each macro-zone of the country.

	Country	Norte Grande	Norte Chico	Central	South	Austral
Mean	3.21	2.63	2.48	3.39	3.25	2.94
N Districts	3100	159	306	1811	712	112
N Population	17,493,434	1,152,860	1,037,356	12,877,596	2,159,730	265,892
Percentage of population according to resilience level						
High and very high	31.1%	4.4%	0.0%	42.2%	26.1%	5.4%
Medium	39.7%	25.2%	7.5%	40.7%	54.5%	38.4%
Low and very low	29.2%	70.4%	92.5%	17.1%	19.4%	56.3%

Figure 2 shows the spatial distribution of the BRIC index throughout the national territory. A heterogeneous distribution of the level of community resilience was found among the different macro-zones of the country. The Central and South macro-zones obtained an average resilience value above the national average. More than 80% of the population in these macro-zones lives in districts with a medium, high, or very high level of community resilience. This represents more than 70% of the national population.

On the contrary, the Norte Grande and Norte Chico macro-zones present the lowest levels of community resilience, with the Norte Chico being the macro-zone with the lowest BRIC score at the national level. Moreover, more than 90% of Norte-Chico inhabitants live in districts with a low or very low level of community resilience, thus representing the most critical macro-zone in disaster resilience.

Regarding the indicators, Table 5 presents the average values of each indicator for the macro-zones concerning the national average. It can be seen that of the five macro-zones, the Norte Grande and Norte Chico contain the largest number of indicators with values below the national average, and, consequently, contain the lowest levels of resilience at the country level. The following sections will address the indicators with the lowest level of resilience by dimension and their differences by macro-zone.

Table 5. Difference in each indicator with respect to the national average by macrozone.

			Differences by Indicator with Respect to National Average				
Resilience Dimension		**Country**	**Norte Grande**	**Norte Chico**	**Central**	**Sur**	**Austral**
Social		*Media*					
% of two-parent households with children	S1	0.26	−0.05	−0.04	0.01	0.00	−0.03
% of households with telephone service available	S2	0.69	−0.19	−0.02	0.02	0.00	0.06
% of households without food insecurity	S3	0.69	−0.01	0.03	−0.01	0.00	0.06
% of population affiliated to a pension fund	S4	0.60	−0.09	−0.05	0.04	−0.08	0.05
% of population with a health insurance system	S5	0.76	−0.16	−0.07	0.01	0.05	−0.10
% of population over 25 who reached basic ed.	S6 *	0.31	−0.11	0.03	−0.03	0.09	−0.05
% of population that speaks Spanish	S7	0.73	0.18	0.03	−0.03	0.03	0.01
% population under 65	S8	0.80	0.05	−0.02	0.00	−0.01	0.03
% population without disability	S9	0.67	0.04	0.06	−0.01	0.00	0.03
Number of doctors per 10,000 inhab.	S10	0.46	−0.19	−0.28	0.07	−0.02	0.04
No. of psychologists per 10,000 inhabitants.	S11	0.51	−0.21	−0.23	0.06	−0.02	0.09

Table 5. *Cont.*

			Differences by Indicator with Respect to National Average				
Resilience Dimension		**Country**	**Norte Grande**	**Norte Chico**	**Central**	**Sur**	**Austral**
Social-Community Capital							
% voter turnout	SC1	0.59	−0.18	−0.03	0.04	−0.04	−0.14
% of population from another country with residence in 2012	SC2 *	0.98	−0.06	0.01	0.00	0.01	−0.03
% of population born in Chile	SC3	0.97	−0.11	0.01	0.00	0.02	−0.02
% of population participating in civil organizations	SC4	0.40	−0.02	0.00	−0.03	0.09	0.00
% of population participating in religious organizations	SC5	0.23	−0.06	−0.11	0.01	0.05	−0.04
% of population participating in volunteering	SC6	0.14	−0.06	−0.05	−0.02	0.06	0.14
Economic							
% gap between both genders	E1 *	0.64	−0.02	0.01	0.00	−0.01	0.06
% of home ownership	E2	0.70	−0.12	0.00	0.01	0.00	0.05
Degree of employment diversification	E3	0.85	−0.04	−0.03	0.03	−0.03	−0.10
% population employed in non-resilient sectors	E4 *	0.72	−0.01	−0.10	0.04	−0.04	−0.07
% population working	E5	0.53	0.13	−0.01	0.00	−0.06	0.18
No. of trading companies	E6	0.12	0.07	−0.05	−0.01	0.01	0.02
Ratio between large and small companies	E7	0.08	−0.01	−0.02	0.01	−0.02	−0.01
Institutional							
Km away from the regional capital	IT1 *	0.98	−0.01	−0.01	0.00	0.00	−0.01
Number of credits and subsidies for agricultural development	IT2	0.06	−0.04	−0.02	−0.01	0.04	−0.02
No. of districts per region	IT3	0.52	−0.49	−0.19	0.11	−0.02	−0.49
Number of people trained by ONEMI	IT4	0.09	0.22	−0.02	−0.01	−0.03	0.12
Number of agricultural insurance policies	IT5	0.36	−0.33	−0.28	−0.01	0.28	−0.33
No. governorates	IT6	0.34	−0.26	−0.17	0.13	−0.21	0.00
Intercensal growth rate 2015–2020	IT7	0.27	0.11	−0.01	0.02	−0.07	−0.04
Infrastructure							
% of households with acceptable materiality	IF1	0.84	−0.10	−0.14	0.00	0.08	0.06
% population with internet access	IF2	0.28	0.04	−0.11	0.04	−0.07	0.07
% Homes built post. thermal standard	IF3	0.41	−0.06	−0.08	0.03	−0.03	−0.07
km railway network per km^2	IF4	0.01	0.01	0.00	0.00	−0.01	−0.01
km road network per km^2	IF5	0.05	−0.02	−0.01	0.01	0.00	−0.04
Distance to airports or aerodromes in km.	IF6 *	0.98	−0.02	−0.01	0.00	0.00	−0.02
Number of educational centers per 10,000 inhabitants.	IF7	0.01	0.01	0.01	0.00	0.00	0.00
No. of coastal protection works	IF8	0.02	0.06	0.00	0.00	−0.01	0.01
Environmental							
% of biodiversity areas	A1	0.04	−0.03	0.03	0.00	0.01	−0.02
% soil without potential erosion	A2	0.45	0.22	−0.05	0.03	−0.07	−0.21
% of surface considered as wetlands	A3	0.04	−0.01	−0.02	−0.01	0.03	0.03
% of protected area (SNASPE)	A4	0.01	0.03	−0.01	−0.01	0.01	0.09
% of arable land	A5	0.27	−0.25	−0.18	0.07	0.01	−0.26
% area without land use change	A6	0.98	0.00	−0.01	0.00	0.01	−0.03
km of rivers per km^2	A7	0.04	−0.02	−0.01	0.01	−0.01	−0.02
Km^2 with water scarcity decrees	A8 *	0.83	0.17	−0.52	−0.01	0.17	0.17
No. of dune fields	A9	0.01	−0.01	0.00	0.00	0.01	−0.01
N° forest industrieser 10,000 inhab.	A10 *	1.00	0.00	0.00	0.00	0.00	−0.02

* The variables were inverted, leaving them with a positive relationship with resilience.

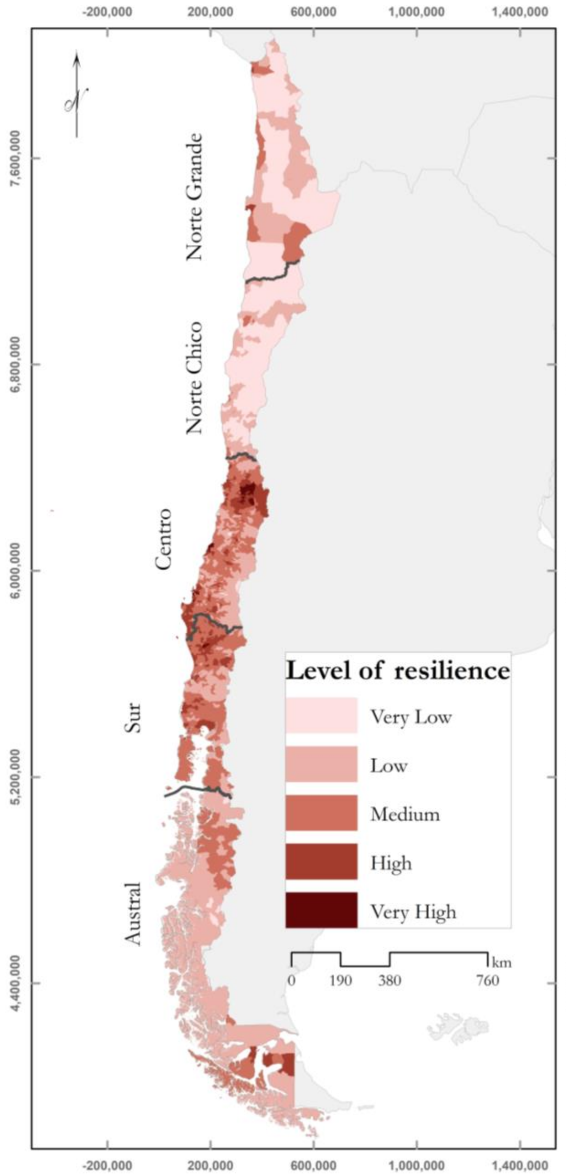

Figure 2. National BRIC Index. Source: prepared by the authors.

3.2. Social Resilience

Table 6 shows the values of the Social-Resilience sub-index obtained for the five macro-zones. The results show that 30% of the national population lives in districts with a low or very low level of Social Resilience. Similarly, the Norte Grande and Norte Chico macro-zones obtained the lowest Social Resilience scores, with about 80% and 57% of their citizens living in districts with a low or very low level of Social Resilience and 0% and 4% in districts with a high or very high level, respectively.

The low levels of Social Resilience in the macro-zones of Norte Grande and Norte Chico are mainly explained by the indicators "percentage of the population over 25 years old who completed basic education" (−0.11/0.03), "the number of doctors per 10,000 inhabitants" (−0.19/−0.28), "number of psychologists per 10,000 inhabitants" (−0.21/−0.23), and the percentage of the population with a health insurance " (−0.16/−0.07), compared to the national average and the rest of the macro-zones in the country (Table 5). Figure 3 shows that the leading group of districts with higher levels of Social Resilience is in the Central macro-zone, specifically in the Metropolitan Region, with 37% of inhabitants located in districts with high or very high levels of Social Resilience. The South and Austral macro-zones have the lowest proportion of citizens residing in districts with low or very low levels of Social Resilience, with values of 14% and 11%, respectively.

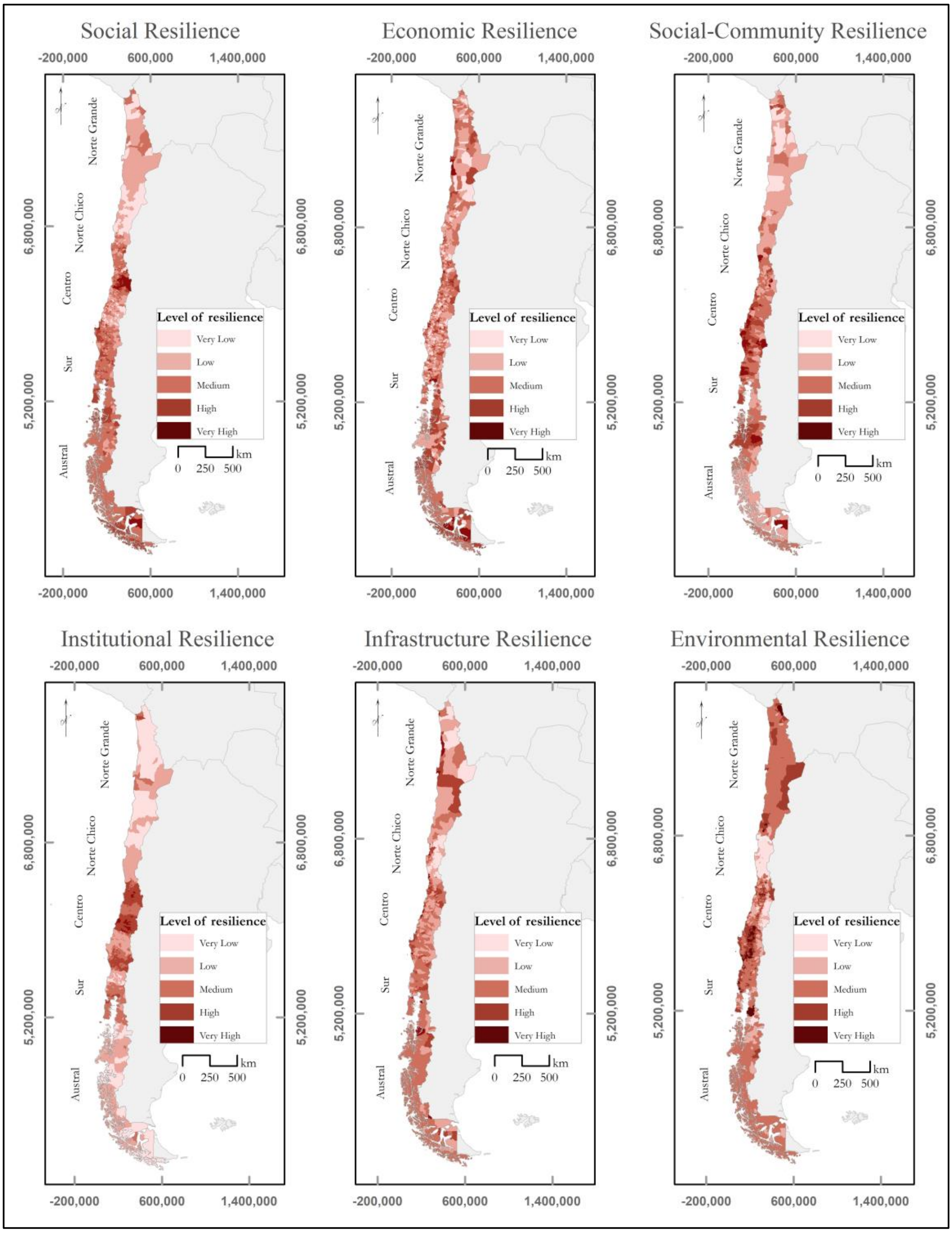

Figure 3. Resilience dimensions of the BRIC Index. Source: prepared by the authors.

Table 6. Average values of the Social-Resilience sub-index and population proportion by level of resilience for each macro-zone of the country.

	Country	**Norte Grande**	**Norte Chico**	**Centro**	**Sur**	**Austral**
Mean	0.50	0.33	0.38	0.53	0.51	0.54
N districts	3100	159	306	1811	712	112
N population	17,493,434	1,152,860	1,037,356	12,877,596	2,159,730	265,892
Percentage of Population according to Resilience level						
High and very high	27.1%	0.0%	4.2%	36.8%	17.7%	31.3%
Medium	42.9%	20.1%	39.2%	34.5%	68.5%	58.0%
Low and very low	30.0%	79.9%	56.5%	28.8%	13.8%	10.7%

3.3. Resilience in Social-Community Capital

At the national level, 32% of the population resides in districts with a low or very low level of resilience in Social Capital (Table 7). Among all the macro-zones, the Norte Grande and Norte Chico once again obtained the lowest levels of resilience, where only 3% and 13% of the population resides in districts with high or very high levels of resilience in Social Capital, respectively.

Table 7. Average values of the Social-Community Capital Resilience subindex and population proportion by level of resilience for each macro-zone of the country.

	Country	**Norte Grande**	**Norte Chico**	**Centro**	**Sur**	**Austral**
Mean	0.64	0.50	0.59	0.64	0.70	0.61
N districts	3100	159	306	1811	712	112
N population	17,493,434	1,152,860	1,037,356	12,877,596	2,159,730	265,892
Percentage of population according to resilience level						
High and very high	28.9%	2.5%	13.1%	25.1%	52.2%	22.3%
Medium	39.1%	17.0%	22.2%	45.8%	34.6%	37.5%
Low and very low	32.0%	80.5%	64.7%	29.0%	13.2%	40.2%

These low levels of resilience in Social-Community Capital are explained by the indicators: electoral participation ($-0.18/-0.03$), percentage of the population born in Chile ($-0.11/0.01$) and percentage of the population participating in volunteering or religious organizations ($-0.06/-0.11$), obtained compared to the national average (Table 5). These are the main factors that trigger low resilience in social-community capital for the country's northern zone. For this dimension, the South macro-zone obtained the highest average score at the national level, with over 50% of its population living in districts with a high or very high level of Community-Capital resilience and only 13% in districts with a low or very low level.

3.4. Economic Resilience

The Central and Austral macro-zones obtained the highest scores in Economic Resilience at the national level, with 77% and 81% of their citizens located in districts with medium, high, or very high levels, respectively (Table 8). On the contrary, the macro-zones of Norte Chico and Sur obtained the lowest scores in this dimension, with about 45% and 46% of their inhabitants residing in districts with a low or very low level of Economic Resilience, mainly explained by a low score in the indicators "percentage of employed population" and "percentage of the population employed in non-resilient sectors" that make up this dimension, presenting negative standard-deviation values compared to the national average, lower than those of the other macro-zones. For the first indicator, values of -0.01 and -0.06 were obtained for the macro-zones of Norte Chico and Sur, respectively, and for the population working in non-resilient sectors of the economy, values of −0.10 and −0.04 were obtained for both macro-zones, respectively (Table 5).

Table 8. Mean values of the Economic-Resilience sub-index and population proportion by level of resilience for each macro-zone of the country.

	Country	Norte Grande	Norte Chico	Centro	Sur	Austral
Mean	0.61	0.61	0.55	0.63	0.56	0.65
N districts	3100	159	306	1811	712	112
N population	17,493,434	1,152,860	1,037,356	12,877,596	2,159,730	265,892
Percentage of population according to resilience level						
High and very high	30.8%	39.0%	17.6%	35.8%	19.2%	49.1%
Medium	38.7%	32.1%	37.6%	41.4%	34.7%	32.1%
Low and very low	30.5%	28.9%	44.8%	22.8%	46.1%	18.8%

Unlike the trend shown in other dimensions of resilience, the districts with high, medium, and low levels are evenly distributed throughout the national territory (see Figure 3).

3.5. Institutional Resilience

Table 9 shows the values of the Institutional-Resilience sub-index obtained for each district at the national level. The Central and South macro-zones obtained the highest scores, with the Central macro-zone being the only one to exceed the national average. For both macro-zones, nearly 80% of inhabitants live in districts with a medium, high, or very high level of Institutional Resilience.

Table 9. Mean values of the Institutional-Resilience sub-index and population proportion by level of resilience for each macro-zone of the country.

	Country	Norte Grande	Norte Chico	Centro	Sur	Austral
Mean	0.48	0.21	0.24	0.57	0.48	0.21
N districts	3100	159	306	1811	712	112
N population	17,493,434	1,152,860	1,037,356	12,877,596	2,159,730	265,892
Percentage of population according to resilience level						
High and very high	39.6%	0.6%	0.0%	56.6%	28.4%	0.0%
Medium	25.8%	13.8%	0.3%	22.1%	51.0%	12.5%
Low and very low	34.6%	85.5%	99.7%	21.3%	20.6%	87.5%

In the Norte Grande, Norte Chico, and Austral macro-zones, a significantly different situation is observed, with 86%, 99%, and 89% of the citizens residing in districts with low or very low levels of Institutional Resilience. This is mainly due to the low scores on the indicators: "number of districts and governorates per region" and "number of agricultural insurance policies" that make up this dimension. The values of these indicators are below the national average in all three macro-zones, as shown in Table 5.

Figure 3 displays the heterogeneity in the distribution of Institutional Resilience throughout the national territory, showing that the concentration of the highest levels of resilience is found in the center of the country and that the most extreme areas are concentrated in the districts with a lower level of Institutional Resilience.

3.6. Infrastructure Resilience

Relatively homogeneous values were obtained for Infrastructure Resilience between the macro-zones, with scores close to the national average of 0.43 (Table 10). The exception to this trend was the Northern-Chico macro-zone, which obtained an average score of 0.33, where 67% of its citizens reside in districts with a low or very low level of Infrastructure Resilience. This situation is due to low values in the following indicators "percentage of households with acceptable materiality" and "percentage of the population with access to the internet", which for this macrozone have values of −0.14 and −0.11, respectively, compared to the national average for both indicators (Table 5).

Table 10. Mean values of the infrastructure-Resilience sub-index and population proportion by level of resilience for each macro-zone of the country.

	Country	**Norte Grande**	**Norte Chico**	**Centro**	**Sur**	**Austral**
Mean	0.43	0.40	0.33	0.45	0.42	0.43
N districts	3100	159	306	1811	712	112
N population	17,493,434	1,152,860	1,037,356	12,877,596	2,159,730	265,892
Percentage of population according to resilience level						
High and very high	25.8%	33.0%	13.0%	33.0%	13.0%	22.0%
Medium	43.2%	20.1%	19.3%	41.3%	61.5%	54.5%
Low and very low	31.0%	47.2%	67.3%	26.2%	25.4%	23.2%

Figure 3 shows the homogeneous distribution of the levels of resilience in infrastructure throughout the national territory.

3.7. Environmental Resilience

The Norte-Chico and Austral macro-zones obtained the lowest scores for Environmental Resilience, with 75% and 39% of their residents living in districts with low or very low levels of resilience, respectively (Table 11). This situation originates from the modest values achieved by the indicators "percentage of arable land", "square kilometers with water scarcity decrees", and "percentage of land without potential erosion" that characterize this dimension. This is reflected in the standard-deviation values presented by these indicators for each macro-zone compared to the national average, as observed in Table 5.

Table 11. Mean values of the Environmental-Resilience sub-index and population proportion by level of resilience for each macro-zone of the country.

	Country	**Norte Grande**	**Norte Chico**	**Centro**	**Sur**	**Austral**
Mean	0.55	0.57	0.38	0.56	0.58	0.49
N districts	3100	159	306	1811	712	112
N population	17,493,434	1,152,860	1,037,356	12,877,596	2,159,730	265,892
Percentage of population according to resilience level						
High and very high	29.1%	18.9%	9.5%	32.9%	34.3%	2.7%
Medium	41.5%	64.2%	15.4%	42.5%	42.6%	58.9%
Low and very low	29.4%	17.0%	75.2%	24.7%	23.2%	38.4%

In contrast, the Central, Norte Grande, and Sur macro-zones obtained scores above the national average, where 25%, 17%, and 23% of citizens reside in districts with a low or very low level of Environmental Resilience.

Figure 3 shows a relatively homogeneous distribution of the level of Environmental Resilience throughout the national territory. The exception to this trend is observed in the Norte-Chico macro-zone, which has the lowest concentration of districts with high levels of Environmental Resilience.

3.8. LISA Analysis

The Moran's global index was IMoran = 0.65, indicating a positive spatial autocorrelation in the resilience levels, suggesting that the BRIC values of each district are related to each other and distributed uniformly in space (Table 12).

The Moran's local index (LISA) highlights that 1290 districts are in the high–high cluster, indicating that more than 30% of the country's districts have levels of resilience like their neighbors above the global average. Meanwhile, the low–low cluster grouped 492 districts with levels of resilience below the global average and their neighboring units. Figure 4 shows that the highest concentration of high–high clusters is found in the Central and Southern macro-zones of the country. In contrast, clusters with levels of resilience below the global average are concentrated in the Norte Grande, Norte Chico, and Austral macro-zones. On the other hand, 610 districts are distributed in the low–high cluster and 16 in the high–low cluster, indicating that only 17.5% of the country's districts have different levels of resilience compared to their neighbors. However, the Moran's and LISA index calculation was estimated for 2763 of the 3100 districts for which the BRIC was calculated due to the number of districts available in the cartography to perform the spatial autocorrelation analyses.

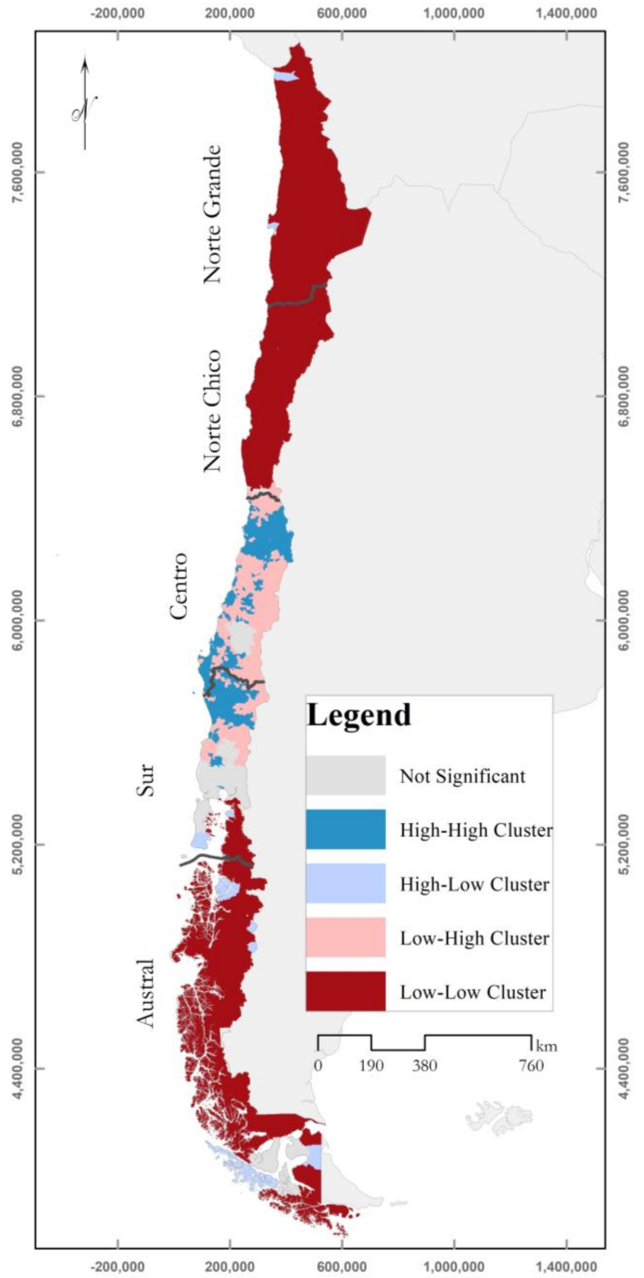

Figure 4. LISA analysis of BRIC Index. Source: prepared by the authors.

Table 12. Global Moran index and local Moran index (LISA).

	BRIC
Global Moran's I	0.65
Z(I)	329.59
LISA cluster categories	Count
Significant local spatial cluster ($p < 0.05$)	
High–high (HH)	1290
Low–low (LL)	494
Counties spatial outliers ($p < 0.05$)	
Low–high (LH)	610
High–low (HL)	16
Not statistically significant spatial clustering ($p < 0.05$)	
Districts	353
Total	2763

4. Discussion

The construction of a national index of community resilience against natural hazards is essential for developing more effective disaster risk reduction policies and to be able to advance in the fulfillment of the eleventh sustainable development goal which seeks to generate more resilient communities in the face of natural disasters and climate change. Even though Chile is highly exposed to multiple natural hazards, it lacks an index that identifies the levels of community resilience throughout the national territory. Therefore, this study's main objective was to develop a national community resilience index using the BRIC model.

First, the results of our study show that the BRIC model can be successfully implemented to obtain a community resilience index for Chile. Our results present characteristics similar to those obtained in previous studies. Like the national BRIC carried out in the United States and Norway, the selected indicators explain more than 30% of the variance in community disaster resilience. When we explore the levels of resilience through a PCA, we also found that, although the indicators included in the study are grouped into different factors, these had a significant correlation to explain the levels of resilience, as in previous studies [18,19]. Thus, the BRIC index is a metric capable of adapting to different social and cultural realities.

Second, our results suggest that the different levels of resilience are not homogeneously distributed throughout the national territory. The BRIC index's calculation shows that the highest levels of resilience are concentrated in the country's Central and Southern macro-zones. In contrast, in the macro-zones at the extremes of the territory (Norte Grande, Norte Chico, and Austral), the greatest proportion of inhabitants are concentrated in districts with the lowest levels of community resilience.

This finding can be explained because Chile's population and resources are concentrated in its central zone. According to the OECD, Chile is characterized by a centralized political administration and economic development model, which generated a hyper-concentration of resources and population in the central zone [59]. Moreover, the central macro-zone generates more than 50% of the national gross domestic product, in addition to housing 73.6% of the national population, mainly in the Metropolitan Region (a region that houses the capital of Chile, Santiago) [55,64]. This significant concentration of resources seems to have generated a regional disparity in various well-being, economic, and environmental development indicators, which could explain the significant differences in the levels of resilience between regions and, consequently, in the development of capacities that allow communities to respond and recover from a disaster. This trend is comparable to that observed in the BRIC studies in Norway [19] and the United States [18]. In both cases, high levels of resilience tended to be found in urban areas. For example, in the case of the United States, it was found that the most resilient counties were those closer to metropolitan areas, having greater access to the services of urban areas in which a large part of the population and services are concentrated. The concentration of resilience levels can also be explained by spatial distribution. Sung and Liaw [20] studied resilience in Taiwan and pointed out that the topography of a place influences resilience levels. In Taiwan, the geographical characteristics of higher or mountainous areas can produce conditions that make the development of the economy and the creation of support networks difficult, among other resources. In the case of Chile, topography could have an impact on resiliency levels given the geographic and climatic differences between the country's five macro-zones. As previously mentioned, areas such as Norte Chico and Norte Grande have extreme climates that could lead to a lower diversification of economic sectors and greater difficulty accessing metropolitan services, among other conditions that could result in lower resilience.

The effects of economic and social development concentration in the country's central zone are evident when the six community resilience dimensions are analyzed. The Norte-Grande and Norte-Chico macro-zones obtained the lowest levels of resilience for almost all the resilience dimensions. In fact, in dimensions such as Social Resilience, Community Capital Resilience, and Institutional Resilience, 9 out of 10 people were found to live in a district with the lowest levels of resilience. Regarding social resilience, it is noted that health indicators, such as having less access to medical doctors or mental-health professionals, can explain the low levels of resilience in Northern Chile. This result is similar to previous studies where cities with the lowest resilience levels also had lower health indicators and a large population dependent on state social assistance. The prevalence of these indicators highlights the importance of developing a health system able to quickly respond to and recover from disasters. It also indicates that the ability to respond depends not solely on individual socio-economic conditions but also on public policies that promote the development of the population in all its dimensions. Regarding the dimension of community capital, the moderate values in the population born in Chile can explain the low levels of resilience in the country's northern region. These results are similar to those found by Cutter et al. [18] in the United States. In seven out of the ten most resilient cities, the high percentage of residents born in the area explained the high levels of resilience. This shows that, for both countries, the percentage of the migrant population could have a significant impact on resilience levels.

This indicator is relevant because it implies the need to develop public policies that facilitate access to support networks for the migrant population. Migrants may encounter many barriers, such as difficulty communicating or receiving assistance in the event of a disaster. Therefore, it is necessary to develop strategies for developing community networks, mainly in the case of the North of Chile, one of the country's macro-zones with the highest migrant population.

Similarly, for Institutional Resilience, not only did the Norte-Grande and Norte-Chico macro-zones achieve the lowest level of resilience, but so did the Austral macro-zone. The remoteness of the most extreme areas from the center of the country can affect the development of local capacities, which can hinder preparedness and response actions when facing a disaster in these communities.

One of the indicators that explains these results is the lack of insurance that protects agricultural resources against various disasters such as floods, and droughts, among others. This is part of the trend found in previous studies, where indicators such as integrating mitigation measures against disasters and preparation plans explained higher levels of institutional resilience. Consequently, the importance of the state investing in actions that allow for improving the capacities of the community and institutions to respond to disasters is evidenced.

On the other hand, although the Norte-Grande and Norte-Chico macro-zones obtain low values in the Economic and Infrastructure Resilience dimensions, they show a more equitable distribution of resilience levels. Chile has experienced sustained economic growth over the past decades, which has allowed local economic development and fostered conditions that favor disaster preparedness, response, and recovery. Specifically, the Austral macrozone is the country's most economically resilient. The diversification of economic sectors could explain this last finding due to the diversity of natural resources available in the macrozone. The positive impact of diversifying sources of employment on resilience is also part of the variables highlighted in the BRIC index of the United States and Norway.

The Sur and Norte-Grande macro-zones appear the most environmentally resilient, showing a meaningful change regarding the national trend. The high value of the Sur macro-zone can be explained by the diverse ecosystem in the area, added to by the large number of protected zones. These measures allow the conservation of natural barriers to mitigate disasters.

5. Conclusions

The construction of the disaster resilience index for Chile shows that the BRIC index is replicable in different contexts. However, some of the index indicators were adapted to the national reality (i.e., considering the availability of information and socioeconomic conditions of the country). This approach enables us to establish indicators representing multiple dimensions of disaster resilience, generating an appropriate characterization of this phenomenon and simplifying its measurement. In addition, the metric's adaptability to different contexts allows the institutions responsible for risk management to use it as a reliable tool when designing policies, plans, and programs to strengthen the country's resilience levels.

The BRIC index also allows the resilience-level distribution throughout the national territory to be characterized to observe the differences between macrozones. In the case of Chile, a country with a vast cultural and geographic diversity, the index highlighted that the macro-zones in the north have the highest percentage of the population with the lowest levels of resilience. These results invite us to evaluate the possibility of targeting resources and strategies to increase resilience in areas with the lowest levels of community resilience. In addition, the differences in the resilience levels between macro-zones highlight the relevance of understanding that the development of resilience dimensions at the local level can facilitate resilience capacity at the national level.

Therefore, our results suggest that in addition to advancing policies, programs, and plans at a national level, it is essential to promote community resilience considering the needs of geographical areas and localities. In addition, it is crucial to advance in strengthening health, migration, disaster insurance development, and environmental-protection indicators as critical areas for resilience development.

Furthermore, it is critical to highlight the need to strengthen the resilience index in its different dimensions. Although the BRIC index is the first approach to characterizing Chile's resilience levels, some limitations exist. Due to the need to adapt to the available data, the sub-dimensions of resilience presented low reliability and low explained variance; however, these were similar to those obtained in previous studies [6,19]. It is critical to advance in the strengthening of the resilience scales and their reliability to measure the desired dimension. For this purpose, it is necessary to consider the importance of the mathematical distribution in the composition of the indicators, together with the theoretical validation. In addition, it is essential to note that the indicators were selected considering communities' capacity to face multiple disasters.

Thus, future research should incorporate additional variables that are adapted to the Chilean reality that can better represent the country's capacities to face and recover from a disaster. It is also essential to differentiate how each indicator of the BRIC index affects the resilience capacity against each threat and assess whether these can be made more relevant for one or more threats.

Another limitation was the scale of environmental resilience. Some of the variables used for this dimension do not respond to the uniqueness of the natural resources in each macro-zone; therefore, it fails to represent the totality of Environmental-Resilience capacities. Thus, it is relevant to advance in updating the indicators that capture each territory's particularities.

Integrating other dimensions that emerge as relevant capacities in disaster response and recovery, such as public-health indicators, is necessary. Including different dimensions would make it possible to adapt and extend the application of the BRIC index to other threats, such as the recent crisis caused by COVID-19.

Finally, our results invite us to develop future work to understand how resilience, through the BRIC index, relates to other indicators relevant to disaster risk management, such as social vulnerability and the population's levels of preparedness. Through this, we can advance in the multidimensional knowledge and measurement of risk, understanding resilience not only as a result of the characteristics and capacities of the population but also as a process of adaptation in the face of different natural hazards. In addition, the spatial patterns of the levels of resilience invite us to explore in future work how these may be related to the topography and geography of the different macro-zones.

On the other hand, it is intended to advance in integrating a bottom-up method that allows the community to raise indicators that can improve its response and recovery capacity against disasters, strengthening collective processes of co-responsibility between communities and authorities.

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