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WATER SCARCITY AND COVID-19 MORTALITY IN RURAL CHILEAN AREAS [1]

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La pandemia de COVID-19, la cual fue provocada por la propagación a nivel mundial del virus SARS-CoV-2 en marzo 2020, ha impactado severamente en muchos ámbitos de la vida y la salud de las personas. Dentro de las principales formas de prevención de la propagación del coronavirus está el lavado frecuente de manos y alimentos, con jabón y agua. Este último es un recurso escaso en varios municipios de Chile, evidenciando dificultades en el abastecimiento de agua a nivel nacional. El presente trabajo indaga la relación entre los municipios decretados en situación de escasez hídrica por el gobierno y los niveles de letalidad al COVID-19 presentados en zonas rurales entre marzo del año 2020 y junio del año 2021. A través de datos estadísticos obtenidos de diferentes bases de datos se correlacionaron las tasas de letalidad con el nivel de desarrollo municipal y el acceso a la red de agua potable. Se obtuvo una correlación negativa entre la alta letalidad al COVID-19 y los bajos niveles de desarrollo comunal y conexión a la red de agua potable, por lo que se considera necesario contemplar las variables geográficas, tales como lo es la escasez hídrica, en la generación de políticas de salud pública y gestión de los recursos hídricos.

Palabras clave: abastecimiento de agua, gestión de los recursos hídricos, COVID-19, zonas rurales, sequía.

The COVID-19 pandemic, caused by the spread of the SARS-CoV-2 virus around the world in March 2020, severely affected many areas of people's life and health. Among the main ways to prevent its spread is by washing hands and food with soap and water. However, the latter is scarce in several municipalities of Chile, highlighting the difficulties of water supply at a national level. This work investigates the relationship between municipalities decreed by the government as being in a situation of water scarcity and the COVID-19 mortality levels found in rural areas between March 2020 and June 2021. Statistical data were used from different databases to correlate mortality rates with the level of municipal development and access to a drinking water network. A negative correlation was obtained between high COVID-19 mortality and low levels of communal development and connection to the drinking water network. As a result, it is deemed necessary to take into account geographical variables, such as water scarcity, in the generation of public health policies and water resource management.

Keywords: water supply, water resource management, COVID-19, rural areas; drought.

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I. INTRODUCTION

The emergence of the SARS-CoV-2 (*Severe Acute Respiratory Syndrome Coronavirus* 2) human coronavirus strain in March 2020, left the world facing a new pandemic. This virus is from a diverse group of coronaviruses that cause mild to severe respiratory infections in humans. In 2002, the SARS-CoV virus (*Severe Acute Respiratory Syndrome Coronavirus*) emerged, and in 2012, the MERS-CoV virus (*Middle East Respiratory Syndrome Coronavirus*), both highly pathogenic zoonotic origin viruses which generated severe respiratory diseases, creating a new public health problem (Cui et al., 2019; Hu et al., 2021).

The SARS-CoV-2 strain causes the COVID-19 disease (*Coronavirus Disease* 2019), whose transmission occurs by direct contact with an infected person through respiratory droplets and by indirect contact through fomites on surfaces located in the immediate environment around the infected person (World Health Organization [WHO], 2020a). In this context, one of the relevant prevention conditions to face the pandemic has been the frequent washing of hands and food using soap and water (World Health Organization [WHO], 2020b), which has increased demand for water to meet the sanitary needs of the population. For this reason, rural areas, threatened by periods of drought experience increased pressure on their water resources than urban areas, such as the case of Semarang in Indonesia, described by Dewi and Prihestiwi (2022).

Heidari and Grigg (2021) and Sivakumar (2021) mention that the availability and accessibility of clean water play a relevant role in the prevention and control of coronavirus in cities. Hence, those regions with water scarcity, high population density, and low availability and accessibility of clean water have a higher risk of contracting the COVID-19 disease. On the other hand, Yuan et al. (2006) commented that temperature, relative humidity, and wind speed influence the survival and transmission rates of coronavirus, so climate scenarios are also factors that can worsen the prevalence and spread.

Given the widespread infections and the novelty of the syndrome, there has been little research dealing with the impact of this pandemic on rural areas in climatic contexts of water scarcity and drought. In this vein, Antwi et al. (2021) analyzed the government response to COVID-19 in drought areas, while Bauza et al. (2021) referred to the practices and challenges regarding water, sanitation, and hygiene in the context of a pandemic in rural areas of Odisha in India.

This article analyzes the impact of the SARS-CoV-2 virus on the fatality rates of the population living in rural areas in Chile with water scarcity, correlating them with the communal development and drinking water access indices. In this way, it is hoped to contribute to the evidence-based debate on how geographical and environmental conditions impact the health of rural inhabitants, particularly under pandemic conditions.

II. THEORETICAL FRAMEWORK

Water scarcity, drought, and the hydrosocial cycle

Water scarcity and drought are two related but dissimilar concepts. Van Loon and Van Lanen (2013) define water scarcity as the overexploitation of a water resource that occurs when the water demand is higher than the availability, i.e., an imbalance between the availability/supply and demand for water. Meanwhile, scarcity is signaled by unsatisfied demand, tensions between users, competition for water, excessive groundwater extraction, and insufficient flows from the natural environment (Food and Agriculture Organization of the United Nations, 2012, p.6). In this context, drought, which is the result of a decreased availability of water resources, may be one of the causes of water scarcity (Pereira et al., 2009).

From this perspective, it is relevant to refer to the hydrosocial cycle as a socio-natural process by which water and society are made and remade in space and time (Guerrero Rojas, 2019; Linton & Budds, 2014). This theoretical representation mentions that water has been reconceptualized, from a purely material point of view, as tangible and observable, and that it can be quantified, exploited, and manipulated, to a socio-natural one (Budds, 2016). In this vein, water scarcity can be understood as the product of the complex relationships between diverse natural and social scenario elements. This is corroborated by Oppliger et al. (2019) who carried out work in the Bueno River basin in Chile, which alludes to the fact that the area's water shortage is not only due to physical causes, such as decreased rainfall, but also to anthropic causes. It refers also to that not all actors in the region suffer from water scarcity, which demonstrates the existence of social factors behind the availability of water sources.

Article 134 of the Water Code (Water Code, 1981) states that areas with water scarcity may be declared as such for a maximum period of one year, extendible successfully, in the face of a severe drought situation.

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From 2008 to November 2021, a total of 189 water shortage decrees were ruled in Chile (General Directorate of Water, 2021). The research mentions that, in the studies on water resources and just as Swyngedouw (2009) suggests, it is relevant to explore the diverse ways in which social power, in its different economic, cultural, and political expressions, is fused with the principles of water management. In this regard, it is transcendental to study how these complex relationships allow responding or not to basic sanitation needs in rural contexts in the face of a pandemic threat, such as COVID-19, and how inequality in access to water can affect the life of the rural population.

Water and health

Stanke et al. (2013) refer to the effects of drought on health, highlighting impacts on nutrition, and increased infection rates related to water, air, biological vectors, and mental health. Likewise, Ebi and Bowen (2015) propose that the effects of drought on health depend on access to sanitary equipment, sanitation, and the individuals' and communities' socioeconomic conditions. For their part, Balbus and Malina (2009) point out that older adults are at risk of morbidity or fatality due to climate-related events, since they are more sensitive to extreme temperatures, given their pre-existing medical conditions and limited mobility. Moreover, Coêlho et al. (2004) and Berman et al. (2021) demonstrate that residents living in drought areas had significantly higher levels of anxiety and emotional distress than residents of areas without drought; there was also higher occupational psychosocial stress among farmers.

Drinking water or wastewater has not been reported as a route of COVID-19 infection (World Health Organization [WHO], 2020c). However, the fact that the SARS-CoV-2 virus can survive in fomites for hours or days suggests that it is a potentially transmissible pathogen through untreated sewage, untreated waste, and soil (SanJuan-Reyes et al., 2021). Both drought and water scarcity, enhanced by climate change, create a favorable scenario for the transmission of pathogens given the infrequent washing of hands and food in these areas, which increases the vulnerability of its inhabitants.

COVID-19 and water scarcity in Chile

Correa-Araneda et al. (2021) proposed that the transmission of the SARS-CoV-2 virus in Chile was mainly related to three climatic factors: minimum temperature, atmospheric pressure, and relative humidity. Transmission was higher in colder, drier cities and when atmospheric pressure was lower. Conversely, Jaque Castillo and Huaico-Malhue (2020) contextualized the situation of older people in the pandemic who were located in rural areas with water scarcity. In addition, the work of the Environmental Group of the United Nations system in Chile (2021) emphasizes the interrelationships between the COVID-19 pandemic and the lack of access to drinking water for thousands of people, which makes it difficult to comply with sanitation measures, since "they are not prepared for the effects of climate change on health [...] and this threatens to reverse years of progress in public health and sustainable development" (Romanello et al., 2021, p. 1620).

The challenge is to understand how the virus has affected Chile's regions, considering the role that environmental variables play in the dynamics of the disease. Similarly, the idea is to contribute more evidence, since this is still an open question that requires more information from all over the world (Correa-Araneda et al., 2021). Along with this, other issues are also important to analyze regarding the pandemic behavior caused by the COVID-19 disease. For example, to investigate its impact on rural and urban areas, health infrastructure, and access to drinking water. All these aspects, which have nothing to do with meteorological variables, present challenges for public management in the face of a climate change scenario and the appearance of new diseases.

III. CASE STUDY

An investigation is proposed regarding the rural and mixed municipalities, which cover 83% of the national territory (615,238 km^2). Of these, those that had water shortage decrees between March 2020 and June 2021 were considered (Figure 1), with a total affected population of 2,517,294 inhabitants.

At a national level, the country has a sanitary service coverage in cities that has reached levels comparable to that of OECD countries, with 99.93% in drinking water, 97.17% in sewage collection, and 99.98% in wastewater treatment with sewer coverage (SISS, 2019). In rural areas, the reality is very different, since this is mainly provided using Rural Drinking Water (RDW) systems, whose upkeep and operation are the responsibility of the State. In this case, drinking water coverage does not exceed 78% and, in terms of sanitation, this does not even reach 45% coverage in this sector (National Water Board, 2022).

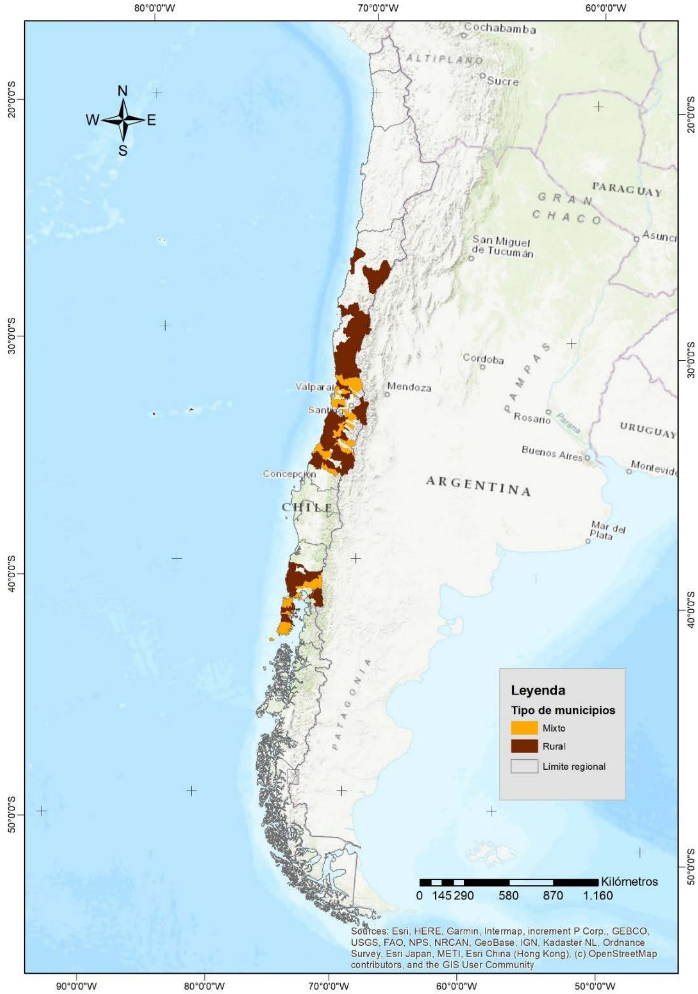

Figure 1. Map of Chile indicating the surface area of the country's mixed and rural municipalities with water shortage decrees until June 2021. Source: Prepared by the authors based on the General Directorate of Water [DGA] (2022).

Concept	Definition
Predominantly rural commune	50% or more of the population lives in census districts of less than 150 inhabitants per km^2, with a maximum of 50,000 inhabitants.
Mixed commune	25% to 50% of its population lives in census districts of less than 150 inhabitants per km^2, with a maximum of 100,000 inhabitants.
Predominantly urban commune	25% or less of the population lives in census districts of less than 150 inhabitants per km^2, with a minimum of 50,000 inhabitants. Apart from the maximum population criterion, communes that are regional capitals are included in this category.

Table 1. Conceptual definitions of municipal characterization associated with its rurality. Source: Preparation by the authors based on the PNDR (2020).

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IV. METHODOLOGY

For the municipal characterization, the classification proposed by the National Rural Development Policy [PNDR, in Spanish] in 2020 was used, which conceptually organizes the municipalities by their degree of rurality (Table 1).

Once this classification was obtained, the categorizations (rural and mixed municipalities) were analyzed and compared with municipalities that have water shortage decrees. Information was taken for the latter from the DGA website (2022), obtaining, in this way, the number of municipalities that had both particularities. Subsequently, the calculation of the fatality rate was made using a percentage, namely, "*the proportion of people with COVID-19 who die, relative to the total number of people who have contracted the disease... amplified to 100 inhabitants*" (Palacios Solís et al., 2021), obtaining the averages and standard deviations of the cases of deaths from March 2020 to June 2021 (Table 2). All this information was obtained from the COVID-19 database of the Ministry of Science, Technology, Knowledge, and Innovation (2021). The calculation of the fatality rate was obtained from the following ratio, which is the estimate used by the World Health Organization [WHO], (2020):

$$\text{Infection Fatality Ratio (IFR, in \%)} = \frac{\text{Number of deaths due to disease}}{\text{Number of people infected}} \times 100$$

Once the fatality rates by municipality had been calculated, they were fed into a geographic information system. Then, they were categorized by Region and Province to obtain a territorial vision of the indicator. The classification by fatality ranges shown in Table 2 was obtained using the natural breaks classification method (*Jenks*), provided by ArcGIS 10.4.1 software.

Fatality ranges	Categorization
2.4 - 3.10	Very high
1.81 - 2.39	High
1.31 - 1.80	Medium
0.59 - 1.30	Low
0.0 - 0.58	Very Low

Table 2. Calculated fatality ranges for COVID-19 in Chilean rural municipalities. Source: Preparation by the authors based on data from the Ministry of Science, Technology, Knowledge, and Innovation (2021).

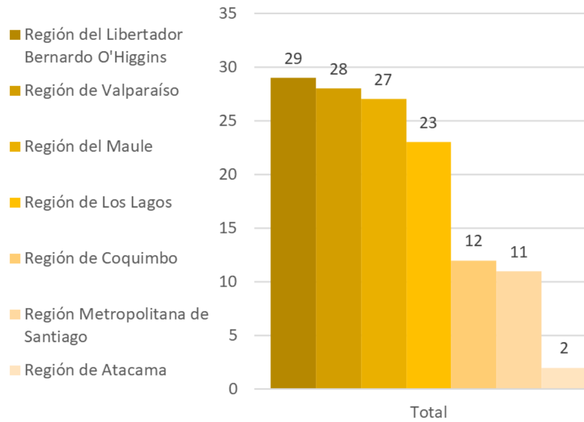

Figure 2. The number of rural and mixed municipalities with water shortage decrees between March 2020 and June 2021. Source: Preparation by the authors based on data from the DGA (2022).

The fatality rates of rural and mixed municipalities were then analyzed considering the Communal Development Index [CDI], obtained from the work of Hernández Bonivento et al. (2020). This is a municipal-level composite index created with data prepared by official Chilean State agencies that were downloadable for the public. In this context, the CDI synthesizes three dimensions, namely health and social welfare, economy - resources, and education. The authors have classified the communes of the whole country by development ranges: high, medium-high, medium, medium-low, and low.

Finally, the fatality data and the drinking water coverage were compared by municipality. The latter was obtained from the Rural Quality of Life Indicators System (2021), which has the percentage of dwellings connected to the drinking water network compared to the total number of dwellings for each commune.

V. RESULTS

Description of the municipalities by regions

There is a total of 167 municipalities affected by water scarcity in Chile, decreed by the Ministry of Public Works - General Directorate of Water (2022) in the analyzed pandemic period. Of these, there are 132 municipalities in the rural and mixed with water scarcity category, while the rest comprise urban municipalities. The three regions with the highest number of municipalities with water scarcity in rural and mixed areas were the Libertador Bernardo O'Higgins, Valparaíso, and Maule regions, while those regions with the fewest municipalities in this condition were the Atacama and the Santiago Metropolitan regions (Figure 2).

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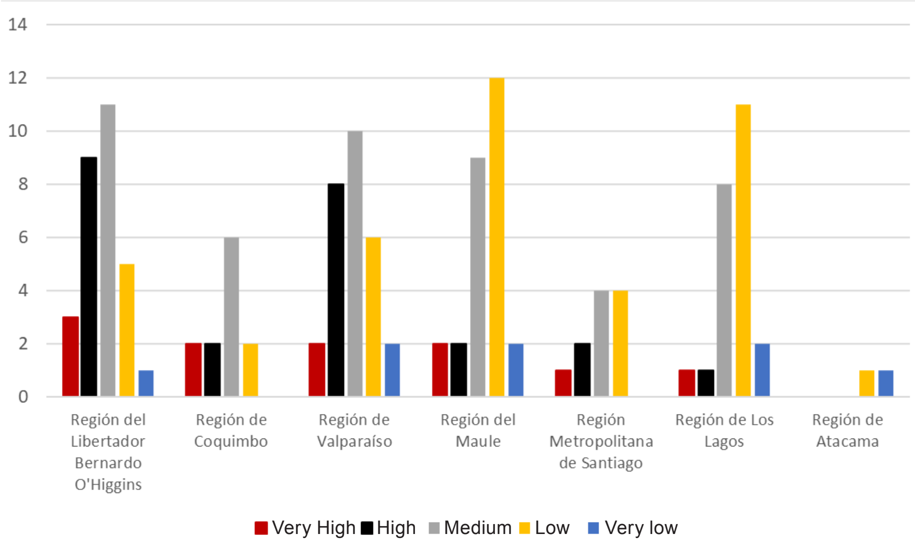

Figure 3. Number of municipalities within the fatality categories by region, organized from very high to very low, from left to right. Source: Preparation by the authors based on data from the DGA (2022) and MinCiencia (2022).

CDI/fatality	Very high fatality %	High fatality %
High CDI	9.1	0.0
Medium-high CDI	18.2	8.3
Medium CDI	9.1	16.7
Medium-low CDI	36.4	66.7
Low CDI	27.3	8.3

Table 3. Communal development index and percentage of municipalities that had very high to high fatality rates. Source: Preparation by the authors based on Hernández Bonivento et al. (2020) and MinCiencia (2021).

Fatality rates in rural and mixed communes in a situation of water scarcity

The average fatality rate for the country in rural and mixed communes, without and with water shortage decrees, was 1.3. On the other hand, the average for those rural and mixed municipalities in a situation of water scarcity was 1.51. In this context, 66 municipalities in a shortage situation are above the latter figure.

When making a regional analysis of fatality rates, the Libertador Bernardo O'Higgins Region has the highest number of rural and mixed municipalities in the very high and high fatality rates category (12 municipalities), followed by Valparaíso. Both regions are characterized by being located in the country's central area, an agricultural area that is currently experiencing a prolonged drought. On the other hand, the regions located towards the northern (Atacama) and southern (Los Lagos Region) extremes were the ones with the fewest municipalities in the "very high and high" categories (Figure 3).

Communal development index and fatality

At a national level, 69% of rural and mixed municipalities with water shortage decrees have a medium-low to low CDI (91 municipalities). Analysis was made, based on this information, comparing the total number of municipalities that had either a very high or high fatality rate and their degree of development. It was observed that there is a relationship between municipality development levels and fatalities, as more than 50% of the municipalities

Commune	Classification	Drinking Water Network (%)	Fatality	Fatality level
San Juan de la Costa	Rural	15.9	2.7	Very high
Cochamó	Rural	34.1	1.5	Medium
Quemchi	Rural	41.8	0.5	Very low
Queilen	Rural	43.3	2.1	High
Puerto Octay	Rural	45.4	1.2	Low
Los Muermos	Rural	46.5	0.8	Low
San Pedro	Rural	47.2	1.4	Medium
San Pablo	Rural	51.5	1.7	Medium
Curaco de Velez	Rural	52.4	0.5	Very low
Canela	Rural	53.1	2.7	Very high
Chanco	Rural	53.5	2.1	High
Puyehue	Rural	54.1	1.6	Medium
Chonchi	Rural	54.4	1.3	Low
Quinchao	Rural	55.3	0.8	Low
Puchuncaví	Mixed	57.6	1.8	Medium
Average		47.1	1.5	
Correlation			-0.28	

Table 4. The fifteen Chilean municipalities that have a water shortage decree and the lowest percentages of homes connected to the drinking water service. The calculation of their fatality rates associated with COVID-19 (2020-2021) is also presented. Source: Preparation by the authors based on INE (2021a) and Min Ciencia (2021).

with high or very high fatality rates have medium-low to low communal development indices (Table 3). Hence, it is inferred that the health, social welfare, and economy-resources levels would significantly impact local capacities to face the pandemic, as there would be an inversely proportional relationship between the CDI of rural municipalities with water scarcity with medium-low and low development and higher fatality indicators.

Drinking water network and fatality

Regarding homes connected to the drinking water network variable, rural and mixed municipalities in a situation of water scarcity had an average of 76.74% with a connection, a lower percentage than the one presented by the country, which is 93% (National Institute of Statistics, 2018). Table 4 shows the 15 municipalities with the lowest connection percentages, whose average is 47.1%. These municipalities, in turn, have a negative correlation index of -0.28, which indicates that, as the fatality rate increases in the communes, the average connection of homes to the drinking water network decreases. Of these communes, three municipalities stand out from the list that have the highest fatality rates and whose connection percentages are well below the service connectivity averages seen nationally and within the same universe: San Juan de la Costa in the Los Lagos region (15.94%), Queilén in the Los Lagos region (43.33%), and Canela in the Coquimbo region (53.07%).

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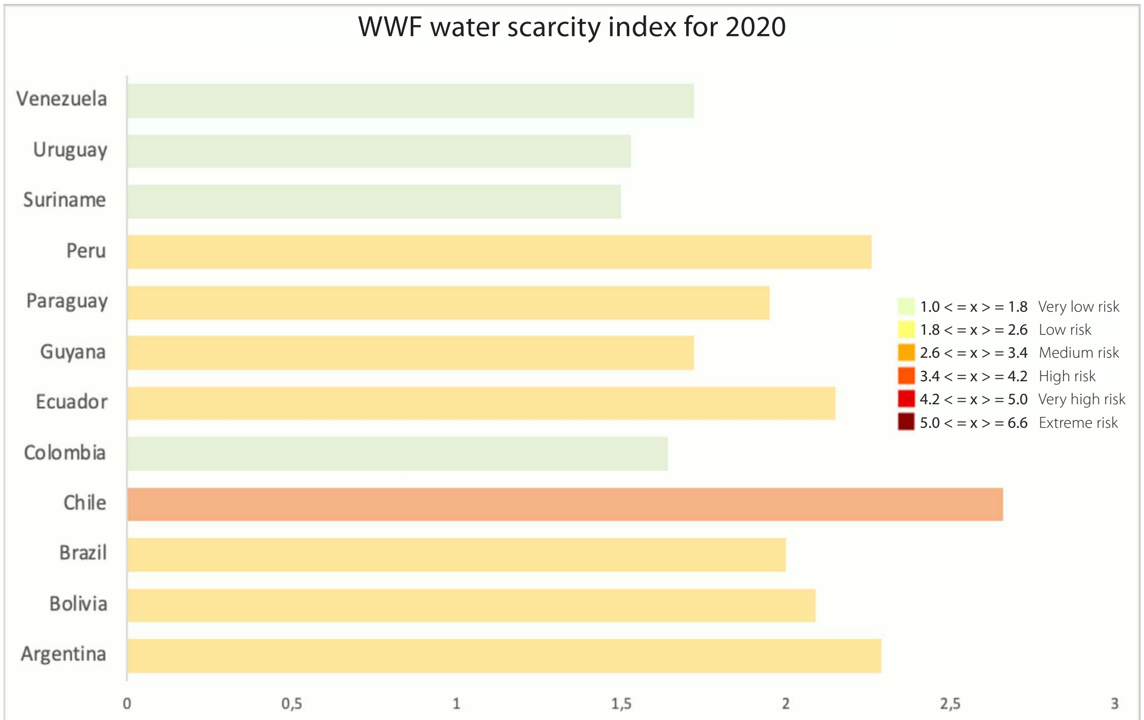

Figura 4. Graph showing the water scarcity index for 2020. Source: Preparation by the authors based on data from the*World Wildlife Foundation* (2020).

VI. DISCUSSION

The first positive case of COVID-19 in South America was confirmed on February 26, 2020, in Brazil. The second, three days later in Ecuador, and subsequently, the spread of the SARS-CoV-2 virus led to the simultaneous infection in countries such as Argentina, Chile, Colombia, Uruguay, and Paraguay, the latter with the first imported case from the same region, from a traveler from Ecuador (Del Tronco Paganell & Paz-Gómez, 2022). According to the latest report of the *Intergovernmental Panel on Climate Change* (2021), an increase in global temperature will increase the frequency and intensity of extreme heat events, heat waves, heavy rainfall, and droughts, namely, there will be "an incessant increase in the impacts of climate change on health and a delayed and inconsistent response from countries around the world" (Romanello et al., 2021, p. 1619). Balbus and Malina (2009) restate this by raising the existence of very few local studies that associate health risk elements and geographical factors, despite this being Sustainable Development Goal (SDG) number 6 of the United Nations.

Chile has one of the highest rates of water scarcity in South America according to the *World Wildlife Foundation* (2020) (Figure 4), which has increased due to the presence of a mega-drought since 2010 (Garreaud et al., 2020). Access to drinking water in Chile is no different from the rest of the continent. However, when the climatic and meteorological conditions and the frequent overexploitation of local aquifers are added, this scenario becomes relevant to face future pandemics.

The intersection between the health (Atzrodt CL et al., 2020) and climate crisis (*Intergovernmental Panel on Climate Change*, 2021) shows that more complex scenarios are generated in the rural areas of the country, as this rural water scarcity scenario reflects the complex dynamics between local actors and their disarticulation with state representatives at regional and national levels (Oppliger et al., 2019). This demonstrates a greater vulnerability for these communities to the effects of the COVID-19 pandemic.

Finally, it will be advisable to move from a reaction approach to pandemics to one of prevention, since, in the fight against future pandemic crises, particularly considering the importance of frequent hand washing, on one hand, it is essential to correctly prepare food to avoid cross-contamination, and on the other, to have "household sanitary services connected to the public network" (Burstein-Roda, 2018, p. 300). Guaranteeing access to water in these areas as well as in rural environments, especially for women, also produces incentives that generate virtuous circles, since it is they who promote environmental awareness and education about water, make financial decisions at home, and suffer the most with domestic chores that involve water.

VII. CONCLUSIONS

The COVID-19 fatality rate was higher in rural-mixed municipalities with low communal development and access to drinking water percentages below the national average. All these municipalities are facing a situation of water scarcity, which has complicated compliance with health measures. In this context, the need to plan prevention strategies is once again evident, considering geographical and environmental conditions, to focus public policies and resources based on the data that this type of research can offer.

In public health studies on the COVID-19 pandemic, no territorialization has been used that considers the phenomenon's different multidimensional variables. This is not just an effect of the drought, i.e., the absence of water resources for basic preventive hygiene practices, such as hand washing, there is also a shortcoming when observing the morbidity indicators. Similarly, decisions made to reduce infections have not looked at public health policies and the effects of climate change in rural contexts, thus making them more vulnerable to the threat of this pandemic.

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