Post-traumatic stress in people from the interior drylands of the Maule region, Chile in the context of climate change

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Abstract

Progressive changes in local environmental scenarios, accelerated by global climate change, can negatively affect the mental health of people who inhabit these areas. The magnitude of these effects may vary depending on the socioeconomic conditions of people and the characteristics of the environment, so certain territories can be more vulnerable than others. In this context, the present study aimed to geographically analyse the levels of psychosocial impact and the types of disruptive responses related to the new territorial scenarios caused by climate change in the coastal drylands of the Maule region, Chile. For this purpose, 223 people from two communes (Curepto and Pencahue) were psychosocially evaluated for post-traumatic stress disorder (PTSD) together with a survey of the prevailing sociodemographic and socioeconomic conditions in relation to the environmental variables of the territory. All information was georeferenced, stored within an ArcGIS Desktop geographic information system (GIS) and then investigated by application of contingency tables, ANOVA and local clustering analysis using SSP statistical software. The results indicated a high level of PTSD in the population, with significant differences related to age and education as well as employment conditions and income. The spatial results showed high PTSD values in the communal capital of Curepto in the central agricultural valley near the estuary of the local river, while the existence of coldspots was observed in the central valley of the Pencahue commune. It was concluded that proximity to population centres and surface water sources played the greatest role for the development of PTSD.

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Introduction

Climate change is directly related to the increase of greenhouse gases in the atmosphere (Crowley, 2000). In general terms, it is manifested by increased temperatures and decreased rainfall leading to climate-related disasters in many parts of the world (Garreaud *et al*., 2017, 2020). Currently, climate change is considered one of the most serious threats at the global level due to physical hazards (Mugambiwa and Dzomondo, 2018), psychological effects (Swim *et al*., 2011; Bostrom *et al*., 2019) and economic risk (Lacroix and Gifford, 2018), as also evidenced in various other studies (Berry and Welsh, 2010; Berry *et al*., 2010; Wu *et al*., 2016).

In 2008, the Task Force on the Interface Between Psychology and Global Climate Change of the American Psychological Association (APA), recommended an investigation of the consequences of exposure to environmental hazards and the psychological responses of people in terms of emotional, motivational, interpersonal and organizational variables (Swim *et al*., 2009). Recent years have seen an increase in the number of scientific studies regarding the impact of climate change (Mares, 2013; Guy *et al*., 2014; Ojala, 2015; Moussa *et al*., 2016; Sacchi *et al*., 2016). These studies reflect aspects of vulnerability from systemic and global perspectives, in particular with respect to the degree of exposure to environmental risks and the multiple interactions between humans and their immediate environment (Mambet *et al*., 2020).

People perceive climate change as a threat, both in the personal and the community sphere (Piya *et al*., 2013) and Doherty and Clayton (2011) inform us that beliefs regarding the direct (proximate) and indirect (remote) consequences of climate change differ and that immediate effects eclipse the uncertainty about future risks. Hayes *et al*. (2019) propose two relevant research areas after an extensive literature review regarding the factors that influence people's mental health caused by climate change. The first considers the impact on mental health by a series of risks arising from a changing climate, while the second relates to the inequity of risks and impacts for people depending on their social and environmental conditions. Based on this, they recommend a series of interventions aimed at improving people's responses and strengthening their mental well-being in a changing climate (Hayes *et al*., 2019).

Post-traumatic stress disorder (PTSD) is considered an important indicator of mental health and disruptive psychological responses after different types of risk scenarios and/or potentially traumatic impacts. PTSD is one of the most prevalent disorders during and after natural disasters in general (Cohena *et al*., 2016; Heid *et al*., 2016; Hayes *et al*., 2019) and specifically earthquakes (García *et al*., 2014), floods (Dai *et al*., 2016) and hurricanes (Pietrzak *et al*., 2012; Paul *et al*., 2014; Rosellini *et al*., 2014; Welton *et al*., 2020). Abeldaño and collaborators (2013) report that the prevalence of post-traumatic stress is higher in areas that are most exposed to environmental hazards, and Leiva-Bianchi *et al*. (2019) have validated this situation and found that people presenting with high levels of responses to disruptive events are spatially located in areas with particular exposure to physical hazards. In this context, when evaluating and monitoring PTSD, the analysis of the spatial location of people can help to detect groups with unsettling mental responses. This allows mapping of areas of particularly strong risk, which can lead to a better allocation of resources and support to community at risk (Lawson *et al*., 2000). Likewise, knowledge of how impacts are spatially distributed in vulnerable populations should improve emergency management and generate emergency plans appropriate to the situation (Cutter and Finch, 2008).

The coastal drylands in Chile's Maule Region have physical characteristics that make them highly vulnerable to the environmental changes of the last decade. Decreased rainfall has generated a mega-drought in the area (González *et al*., 2018; Garreud *et al*., 2020), with the annual average rainfall changing from 722.1 mm in 2008 to 379.3 mm in 2019 according to records of the Chilean Meteorological Directorate (DMC, 2008, 2020). The Ministry of Public Works (MOP) has officially recognized this condition by including it in the decrees of water scarcity N°161, 155, 95, 102 and 33 (MOP, 2011, 2014, 2018, 2019, 2020). The coastal basins are highly dependent on the amount of rainfall, and the decrease in channelled water flow as well as of ground water levels has been devastating. As a consequence, overexploitation of the sources to maintain water supply, both for household use and agricultural needs, has in some areas led to provision of drinking water through tanker trucks (Tapia, 2019). Other negative effects include impact on livestock and dams used for agriculture and other farming schemes (Baechler *et al*., 2012). This state of affairs, together with the predominance of large areas of forest monoculture (Díaz-Hormazábal and González, 2016), loss of the native vegetation cover and extreme temperatures throughout the area, has led to forest fires that now occur at greater frequency and magnitude than any time earlier. Since much of the fires originate in sectors close to communication routes and populated areas (Díaz-Hormazábal and González, 2016), both areas for food production and those used for homes (towns and villages) are at risk.

The insufficiency of water, both for human consumption and breeding animals, is aggravated by growing rainfall irregularity together with the general temperature increase and recurrence of heat waves. Vulnerable environmental conditions of this kind is generating high levels of stress in the population of the coastal drylands of the Maule region (Centro de Ciencia del Clima y la Resiliencia, 2015). It is therefore relevant to study the impact of social and psychological parameters on the population exposed to territorial vulnerability due to the changing geographical and environmental variables. The objective of this study was to spatially analyse the levels of impact and the types of disruptive psychosocial responses related to the new territorial scenarios originated by climate change in the coastal drylands of the Maule region, Chile.

Materials and methods

Study site

The 10-year mega drought recorded in central Chile has caused a 40% reduction in rainfall, which is directly related to the progressive global climate change (Garreaud *et al*., 2017, 2020). In the last decade, the rain-fed sector has been particularly affected by a mega-drought period that has generated a decrease in water reserves not only affecting human consumption and agricultural activities, but also resulting favourable conditions for large forest fires. The communes Curepto and Pencahue, located in the drylands of Maule (Figure 1), were chosen as they were among the most affected by these events. Although there are some differences, both communes have a mainly Mediterranean type due to the proximity to the Pacific Ocean (DMC, 2008).

Curepto is characterized by a coastal mountain range and receives the oceanic influence directly in its western section, while a valley with a river (Mataquito) in its northern section facilitates the entry of this coastal influence for a few tens of km. The river and its aquifers play a decisive role manifested by a great decrease in its flow in recent years. The monthly average flow average in the 80s had values between 199.3 m^3/sec and 201.3 m^3/sec, registering a maximum in 1987 of 920.07 m^3/s. Currently, however, the flow average is 153 m^3/sec, reach values as low as 0.37 m^3/sec in summer (Baechler *et al*., 2012; Lema, 2021). These periods of low flow are increasingly extensive, as there is no rainfall in the upper part of the basin, which depletes the snow reserves of the high mountain range.

Curepto is a mainly rural commune with 9448 inhabitants distributed between a main urban nucleus that reaches the town category, some smaller populated areas and most of the population (78.5%) living in the rural areas. In addition to the communal capital that is also called Curepto, there are two village-level population centres called Gualleco and Huaquén (Secretaría de Planificación Municipal Ilustre Municipalidad de Curepto, 2017). The average altitude is 219 m above the mean seas level (mamsl), with the highest top at 839 mamsl. The communal territory is predominantly mountainous and located between the coastal plains and the mountain range with river terraces in the middle, especially in the north-western part. The river Huenchullamí drains the main coastal basin and marks the south-western limit of the commune. The agricultural activities are concentrated in the valleys where annual crops alternate with plantations, which mainly consist of vines and blueberries. Forest plantations of pine and eucalyptus dominate the hills.

Pencahue, in contrast, is completely set in the leeward part of the coastal mountain range, so the climate produces a steppe-like stretch of land. The river Maule drains the land at its southern boundary, where the coastal influence is less, given the distance between the commune and the coast. With 70.8% rural population that reaches 8245 inhabitants together with those living in the two villages Curtiduría and Corinto (Ilustre Municipalidad de Pecahue, 2019), the two communes are similar population wise. The communal territory, mostly located along the coast mountain range, has an average altitude of 235 mamsl, with the highest top at 840 mamsl. There is a relatively flat area in the Southeast, which corresponds to the valley generated by Los Puercos Estuary, around which a large part of the communal population is concentrated. The main agricultural activities, with crops of vines and olive, are concentrated and watered by the Pencahue irrigation canal that takes water from the Claro River. In the sectors with steeper slopes, pine forest plantations dominate.

Study subjects

The study participants were selected through a conglomerate sampling that considered a similar ratio between urban and rural inhabitants, in both communes. Out of the total sample of 223, 118 were inhabitants of Curepto and 105 of Pencahue. The sectors of interest were initially identified according to the distribution of population registered in the census as rural polygons and urban blocks. A geographic information system (GIS) approach was used to visualize these sectors and we then proceeded to determine the number of people to be considered in each sector and block, according to the sample from each commune. For this, homes were chosen at random within each sector and block according to a systematic distribution. In each case, an adult was interviewed, preferably the head of household; if not found, the participation of another adult living in the same address was requested. The data collection was carried out safeguarding the privacy of the identity of the respondents taking care that the informed consent could not be related to the survey. The location of the selected homes was saved in the GIS database including access routes and field sampling maps.

Survey

The data collection was carried out through a psychosocial data approach that included a declaration of informed consent to participate in the research, application of a PTSD scale (Norris *et al*., 2008), and characterization of the respondents considering three sociodemographic variables (gender, age and education level) and two socioeconomic ones (household income and employment status); others factors like religion or ethnicity were not considered because they were not considered relevant for the population under study.

To measure the stress symptoms in the people, a PTSD rating interview was applied using SPRINT-E with 12 items in total (such as adaptation to daily life, alcohol consumption, drug use, suicidal ideas, *etc*.) as described by Norris *et al*. (2008) and Leiva-Bianchi and Gallardo (2013). Each item was measured on a scale ranging from 0 (minimum level) to 3 (maximum level), allowing 36 points in total. Symptoms with scores of 2 or higher were considered as intense, and persons showing 3 or more intense symptoms were considered to be PTSD cases. The location of each person surveyed was georeferenced using a Garmin receiver model GPSMAP 64scx, in order to study spatially possible interactions between environmental conditions and the level of post-traumatic stress registered in people.

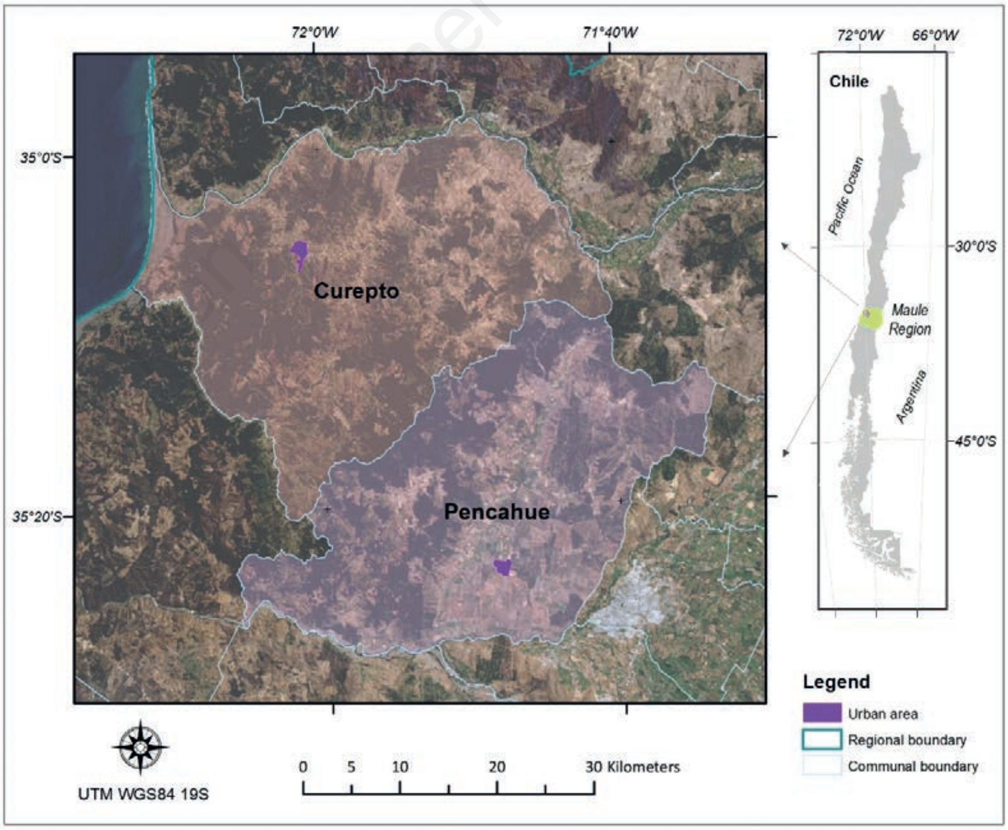

Figure 1. Localisation of the study area in Chile.

Environmental characterization

Geographic information representing both spatial and environmental variables that can potentially affect PSTD in people was collected (Lería, 2016; Sandoval-Díaz and Cuadra-Martínez, 2020). In this regard, the variables of particular relevance in the study territory and those that could have some relation with the effects of climate change were considered, so that the contextual variables of both communes were spatially represented: i) proximity to water sources, considering elements of the local hydrographic network such as rivers, streams and canals (DISTASW); ii) the altitude of the site, which is related to surface runoff and available groundwater reserves (ALTITUD); iii) land use, which determines the physical environment in which people live (LANDUSE); iv) proximity to sites where large forest fires have occurred in the last 5 years (DISTAFF); v) the number of forest fire outbreaks recorded in the last 10 years (NUMFFF); vi) proximity to population centres, which can serve as places to find support from other people or institutions in case of environmental affectations (DISTAPC); and vii) the type of closest population centre, which can determine the type of support that people obtain in case of environmental affectations (TYPEPC).

Data of each variable of the physical environment, in addition to socioeconomic and psychosocial data, were added to the attribute table of the point coverage that represent the spatial location of each person surveyed. This GIS layer of points brought together all the data collected, thus facilitating its handling and subsequent statistical and spatial analysis.

Statistics and local cluster analyses

The G*power software, version 3.1.9.7 (http://www.gpower.hhu.de) was used to calculate the sample size of the contingency tables and ANOVA (ANalysis Of VAriance). For both, a medium effect size (SE=0.3), a P>0.05 level of significance and a statistical power (1-β) of 0.9 were configured. To meet these parameters, at least 194 is required for the contingency tables and 162 for ANOVA.

Statistical analyses for ANOVA tests and contingency tables were performed by means of SPSS 14.0 software. A bivariate analysis was performed considering two stages:

i) An analysis of contingency tables was first completed in which frequency, percentage and association for categorical variables were obtained together with the contingency coefficient (CC) that takes a value between 0 and 1, where the latter indicates a perfect association at P<0.05. The corrected typified residuals (CTR), which assumes a normal distribution with mean of 0 and a standard deviation (SD) of 1, were also obtained. A CTR with a confidence level (CL) of 95% greater than 1.96 indicates that there are more cases than expected if the variables were independent, while a value lower than –1.96 indicates that there are fewer cases than expected if the variables were independent (Pardo and Ruiz, 2005). In this context, the analysis of contingency tables was carried out to determine if there was a relationship between PTSD and the sociodemographic variables (commune, gender, age and level of education) and the socioeconomic ones (household income and employment status).

ii) Secondly, an ANOVA (Pardo and Ruiz, 2005) was carried out to determine if there were significant differences in the level of PTSD with respect to the different alternatives of the considered variables of the physical environment (DISTASW, ALTITUD, LANDUSE, DISTAFF, NUMFFF, DISTAPC and TYPEPC).

Finally, a local cluster analysis (Getis-Ord General G) was performed using ArcGIS software version 10.5 (Leiva-Bianchi *et al.*, 2019), in order to identify spatial concentrations of low or high levels of PTSD in the study area. It was considered that the entity must have an extreme value to constitute a statistically significant hotspot or coldspot that requires results in one area be surrounded by other areas with similar values.

Results

According to the results obtained, 79.3% of the total sample of people evaluated (N=223) were recorded as being PTSD cases. Table 1 shows the details of the distribution of PTSD cases detected according to the sociodemographic variables considered.

The communes investigated had a similar level of PTSD, 84.7% in Curepto and 73.1% in Pencahue. Although there was a low level of differentiation between communes (CC=0.142 at

Table 1. Association between post-traumatic stress disorder levels and sociodemographic variables.

Attribute	Specific variable	N	%	% PTSD	CTR	CC
Commune	Curepto	118	52.9	84.7	2.1	0.142*
	Pencahue	105	47.1	73.1	–2.1	
Gender	Male	94	42.2	74.5	–1.5	0.101
	Female	129	57.8	82.8	1.5	
Age	18-34 years old	22	9.9	86.4	0.9	0.218*
	35-44 years old	34	15.2	64.7	–2.3	
	45-54 years old	46	20.6	84.8	1.0	
	55-65 years old	56	25.1	89.1	2.1	
	>65 years old	65	29.2	72.3	–1.6	
Level of education	None	13	5.8	100.0	1.8	0.258*
	Basic incomplete	58	26.0	77.6	–0.4	
	Basic complete	39	17.4	87.2	1.3	
	Middle incomplete	26	11.7	88.5	1.2	
	Middle complete	57	25.6	73.7	–1.2	
	Highschool	14	6.3	85.7	0.6	
	University	16	7.2	50.0	–3.0	

PTSD, ost-traumatic stress disorder; CTR, corrected typified residuals; CC, contingency coefficient; *Statistically significant at P<0.05.

P<0.05), Curepto had a significant association (CTR>1.96) with a greater number of PTSD cases than expected. Both males and females showed a high percentage of PTSD, *i.e.* 74.5% and 82.8%, respectively. The low level of association (CC=0.101 at P>0.05) and the absence of CTR above 1.96 or below –1.96, indicates that the variables were independent. Among the age groups, significant differences of PTSD were observed (CC=0.218 at P<0.05). Specifically, for the age group 35-44 years, there were fewer PTSD cases (64.7%) than expected (CTR< –1.96), while for the 55-65 years group had a higher number of cases (89.1%) than expected (CTR>1.96). With respect to education, there were also significant differences in the number of PTSD cases detected (CC=0.258; P<0.05). Those lacking any kind of schooling were all affected (CTR>1.96) in contrast to people with university-level education, for whom only half who showed PTSD (CTR<–1.96).

With regard to the socioeconomic variables, we noted that 77% of the population investigated receive less than 399,000 CLP (minimum monthly salary ≈ 337,000 CLP ≈ 433 USD). As seen in Table 2, a large number of the people in the communes under study were home owners (43%), 21.1% of them had work but without contract and about as many (21.5%) were retired.

The level of household income were associated with PTSD (CC=0.216 at P<0.05), with a strong presence in the group that earns less than 200 000 CLP per month (91.8%), which was significantly higher than expected (CTR ≥1.96). In contrast, we saw less PTSD (68.3%) than expected (CTR ≤ –1.96) among those earning intermediate salaries (400,000-600,000 CLP). There was a relatively strong association between employment and PTSD (CC=0.240 at P<0.05), but for those with an employment contract there were fewer cases of PTSD (57.1%) than expected (CTR ≤ –1.96). On the other hand, as can be seen in Table 3, there were significant differences in relation to PTSD between the communes with

Table 2. Association between post-traumatic stress disorder level and socioeconomic variables.

Attribute	Specific variable	N	%	% PTSD	CTR	CC
Household income	<199,000 CLP	61	27.4	91.8	2.8	0.216*
	200,000-399,000 CLP	110	49.3	75.2	–1.5	
	400,000-599,000 CLP	41	18.4	68.3	–1.9	
	>600,000 CLP	11	4.9	90.3	1.0	
Social situation	Unemployed	15	6.7	93.3	1.4	0.240*
	Student	5	2.3	100.0	1.2	
	Employed without contract	47	21.1	72.3	–1.3	
	Fixed-term employment	12	5.4	91.7	1.1	
	Employment contract	21	9.4	57.1	–2.6	
	Retired	48	21.5	77.1	–0.4	
	Homeowner	75	33.6	85.1	1.5	

PTSD, post-traumatic stress disorder; CTR, corrected typified residuals; CC, contingency coefficient; CLP, Chilean peso. *Statistically significant at P<0.05.

Table 3. Post-traumatic stress disorder level as related to the environmental variables.

Attribute	Specific variable	PTSD Curepto		PTSD Pencahue		F
		Mean	SD	Mean	SD	
DISTASW	0-249 m	15.07	8.04	14.86	6.07	5.228*
	250-499 m	19.38	9.68	13.97	7.64	
	500-999 m	22.29	6.31	15.36	7.61	
	≥1000 m	25.43	6.68	13.79	7.90	
ALTITUD	<1000 mamsl	17.99	8.76	14.95	7.35	0.122
	≥1000 mamsl	17.70	9.62	13.81	6.51	
LANDUSE	Urban-industrial	17.30	8.55	15.64	6.62	2.361
	Farming	18.60	9.47	14.75	6.59	
	Meadow-shrub	18.41	8.70	13.61	9.11	
	Forest	20.00	10.84	8.14	3.48	
DISTAFF	0-4.9 km	16.39	8.10	12.96	6.54	0.392
	5-9.9 km	17.89	10.21	15.15	7.36	
	≥10 km	19.97	8.86	14.82	7.00	
NUMFFF	0-4 hotspots	20.62	8.89	13.75	7.21	2.036
	5-9 hotspots	16.74	8.66	13.24	6.75	
	≥10 hotspots	13.00	0.00	16.14	7.19	
DISTAPC	0-4.9 km	17.81	8.23	15.28	7.17	3.417*
	5-9.9 km	19.64	10.35	11.60	8.46	
	10-14.9 km	16.00	9.43	15.59	7.24	
	≥15 km	25.33	6.09	12.94	6.08	
TYPEPC	Town	15.23	8.53	16.04	6.68	4.201*
	Village	20.20	8.33	15.40	6.58	
	Rural	18.65	8.96	13.76	7.45	

PTSD, post-traumatic stress disorder; SD, standard deviation; F, the ratio of explained variance to unexplained variance. *Statistically significant at P<0.05.

respect to the following environmental variables: i) DISTASW, corresponding to the proximity to surface water courses (F=5.228 at P<0.05), showed for Curepto commune - the greater the distance, the higher the level of PTSD. However, Pencahue commune presented a more diffuse pattern; ii) DISTAPC, corresponding to the proximity to population centres (F=3.417 at P<0.05), presented a clear trend for Curepto - the greater the distance, the higher the level of PTSD. Again, Pencahue did not show a defined pattern; and iii) TYPEPC, corresponding to the nearest type of population centre (F=4.201 at P<0.05), showed a tendency for Curepto - the larger the population centre, the lower the level of PTSD. In contrast, proximity to large population centres implied higher levels of PTSD in Pencahue.

The spatial distribution of the PTSD levels (Figure 2) indicates that high values were concentrated in the northern part of the study area (in Curepto), specifically in the vicinity of the river Mataquito. This can be attributed to the large negative variation in its flow in recent years, which has affected the availability of water in the area.

When observing the result of local cluster analysis (Figure 3), the existence of PTSD hotspots was detected around the communal capital of Curepto (the central agricultural valley near the estuary) and around the village Huaquén (a locality close to the river) in the same commune. On the other hand, the existence of coldspots was observed in Pencahue around its central valley in the extreme North and South.

Discussion

Although high for both communes, there were clear differences with respect to the PTSD levels registered in their populations. In general, the sociodemographic and socioeconomic conditions generated a high impact, while the results relating to well-being (certain age ranges, higher education, higher income, work stability) were associated with lower PTSD levels. In contrast, less education or low income showed higher PTSD levels. On the other hand, a clear influence in the PTSD levels by the physical environment was noted, *e.g.*, Curepto being more dependent on specific water availability for agricultural activities, presented higher levels, which were spatially more concentrated than in Pencahue that is more accustomed to a rain-fed environment. The concentration of detected hotspots in Curepto was found to be directly related to the great changes registered in the Mataquito river and its sources as well as decrease in groundwater due to increasing demand for drinking water, irrigation and mining activities (Peña, 2018).

The results confirm that climate change has serious consequences for communities and people's livelihoods through physical, geographical and psychological implications that directly affect the mental health of people and their functioning as presented by Swim *et al*. (2009) and Mugambiwa and Dzomonda (2018). Particularly, our findings corroborate that environmental changes caused by climate change directly affect mental health (Hayes *et al*., 2019) causing post-traumatic stress disorders, anxiety, depres-

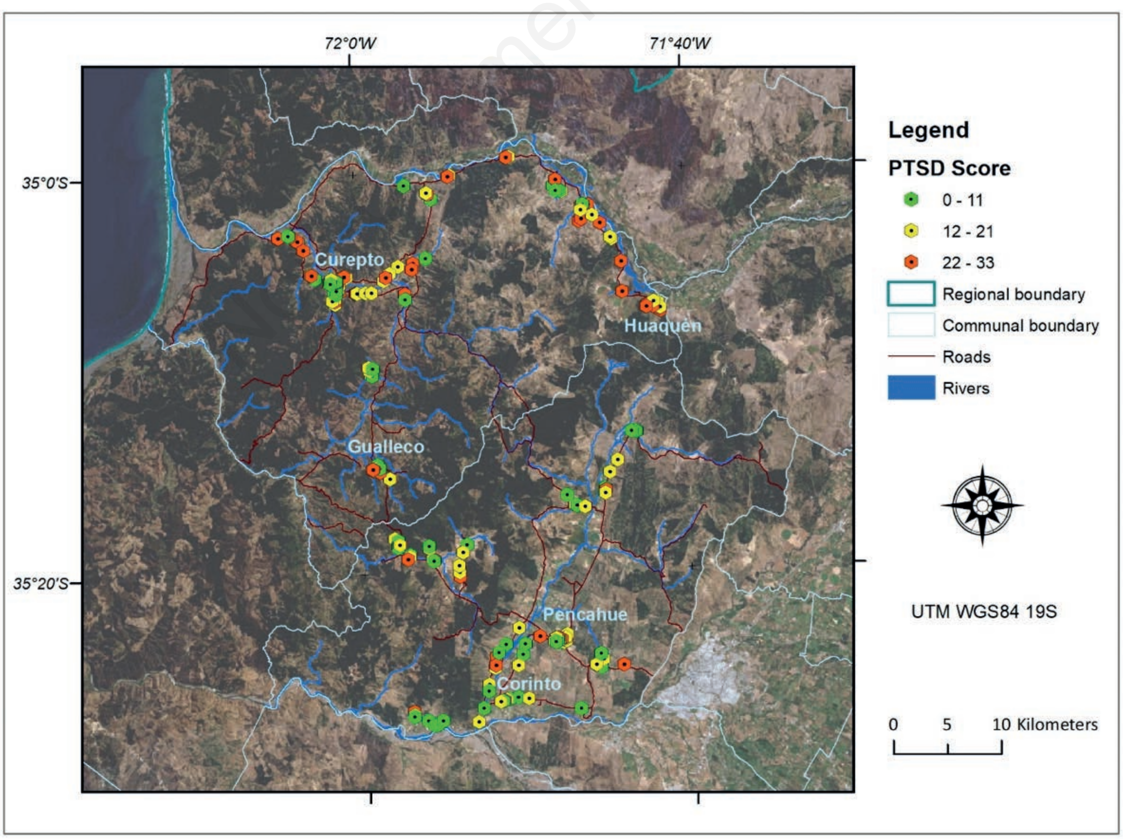

Figure 2. Spatial distribution of the post-traumatic stress disorder level in the communes of Curepto and Pencahue.

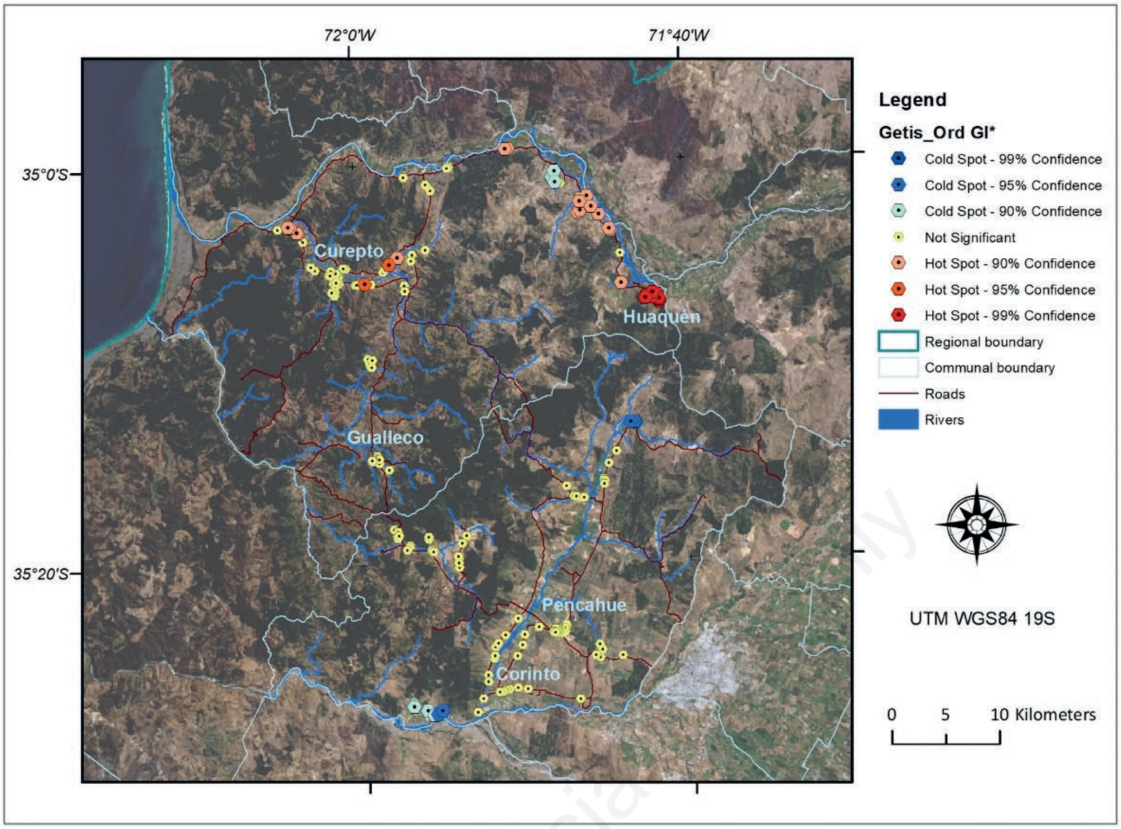

Figure 3. Spatial distribution of post-traumatic stress disorder in the communes of Curepto and Pencahue.

sion and general increase of stress levels. Although this can be addressed by conservation of resources (COR), a theory stating that serious trauma occurs when personal, social or material resources are suddenly lost (Hobfoll, 2014), people who have seen their personal resources threatened due to sustained exposure to environmental changes present increased levels of post-traumatic stress. The strong mental responses seen in Curepto and Pencahue can be explained by the proximity to the environmental hazards experienced, since people exposed to unavoidable, critical events present psychosocial impacts (Abeldaño *et al*., 2013; Leiva-Bianchi *et al*., 2019). In addition, post-traumatic stress symptoms can persist for years in areas after this kind of exposure (Leiva-Bianchi *et al*., 2020). Thus, disruptive events and the intensity of its psychological effect they cause should be considered when investigating how people perceive, process and respond to changing environmental situations as such important factors can guide actions aimed at tempering personal responses and improving the overall situation (van der Linden *et al*., 2015).

Conclusions

Sociodemographic conditions, such as age and level of education, and socio-economic conditions, such as employment and income, have a positive or negative effects on PTSD levels registered in people living in areas exposed to environmental changes. This is particularly obvious in territories strongly affected by climate change. As seen here, the level of proximity to adverse events as well as to protection or threat elements can alter these levels. In the study area, places most negatively affected were identified as those with a greater dependence on water resources where the situation had been aggravated by drought caused by climate change. Evaluating the post-traumatic stress associated with scenarios of environmental change should consider the sociodemographic and socioeconomic conditions of exposed populations and their spatial relationship with respect to the existing protection or threat elements, in order to correctly guide the implementation of recovery actions.

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