International Journal of Disaster Risk Reduction 50 (2020) 101703

Contents lists available at ScienceDirect

International Journal of Disaster Risk Reduction

journal homepage: http://www.elsevier.com/locate/ijdrr

Barriers to the implementation of international agreements on the ground: Climate change and resilience building in the Araucanía Region of Chile

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ARTICLE INFO

Keywords:
resilience
Climate change adaptation and mitigation
Disaster risk reduction
Sustainable development
Policy implementation

ABSTRACT

Implementing disaster risk reduction (DRR), climate change adaptation and mitigation (CCA/M), and sustainable development are key to increasing community resilience to pressing climate change risks. Barriers to grassroots implementation of national and international policies are inexorably linked to local contexts, and in-depth understanding of these barriers is crucial in areas greatly impacted by climate change. This research applied an empirical mixed-methods approach to identify the barriers to implementing grassroots climate resilience in the Araucanía Region in central-southern Chile. Data was collected in the form of expert interviews, 454 questionnaires of community members, community focus group discussions, and historical climate data for the region. The need to strengthen local-level implementation persists in the Araucanía Region. Barriers to implementation include limited horizontal and multi-sectoral governance, and inadequate allocation of human and financial resources at the local level. The majority of community members expressed that they had some (71% n = 322) or a lot (10% n = 47) of climate change knowledge, with 91% (n = 409) indicating that their community is impacted by climate change, and half correctly perceived changes in several climate-related hazards. However, a misconception held by experts regarding community knowledge represents a barrier that limits opportunities for leveraging community willingness to take action, and impedes the inclusion of community priorities into national policies. Opportunities exist to strengthen grassroots climate resilience by adopting a coherent approach which links DRR and CCA/M to key community concerns in sustainable development. National and regional actors need to work closely with municipal governments to mobilize synergies and foster meaningful grassroots action.

1. Introduction

Resilience to disaster and climate change risks is critical for achieving the Sustainable Development Goals (SDGs). Strengthening the coherent implementation of the SDGs, Sendai Framework for Disaster Risk Reduction and Paris Agreement on Climate Change is vital in this process [1,2]. However, major gaps remain in current knowledge, particularly around how long-term focuses of climate change adaptation and mitigation (CCA/M) can be more effectively tied to sustainable development outcomes and disaster risk reduction (DRR) [3,4]. Furthermore, increasing implementation on the grassroots level is critical to improve community resilience to climate change.

The community is a critical element in addressing disaster and climate change risks [5] and the implementation of climate resilience is often framed as a local responsibility [6,7]. However, numerous barriers remain despite concerted efforts to strengthen the implementation of climate resilience on the community level. Spires et al. [4] identified a typology of barriers to community-based CCA through a review of academic literature. This typology has been confirmed by a recent review of grey literature [8]. These barriers include: 1) social (or socio-political); 2) resource, and 3) physical [4,8]. Social-political barriers result from the social, political and cultural context of implementation. They include principles such as governance and structures (including policies and coordination), cognitive and behavioral factors (attitudes, perceptions, beliefs, values and behaviors of community members), communication (e.g. on priorities for CCA), and inequality (e.g. discrimination of some vulnerable groups limiting meaningful participation) [4,8]. Resource barriers refer to the absence of key resources required to ensure effective implementation, such as knowledge, technology, finances and human resources [4,8]. This includes both

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https://doi.org/10.1016/j.ijdrr.2020.101703
Received 18 December 2019; Received in revised form 19 May 2020; Accepted 1 June 2020
Available online 22 June 2020

institutional capacity on a technical level, and the availability of information to inform local decision-making [4,9]. Physical barriers refer to the impact of climate change on infrastructure [4,8]. Community-based approaches to climate resilience, as well as the barriers to their successful implementation, are context specific [4,8,10]. Furthermore, there is an explicit call in the literature for empirical in-depth case studies to deepen the understanding of barriers to such approaches [4].

Community-based approaches to climate resilience are important as communities are often on the front lines of disaster impacts [7,9,11]. The engagement of community stakeholders is critical for establishing and addressing community priorities and attaining goals for long-term sustainability [9,12]. Furthermore, synergies and trade-offs between these policies most commonly materialize at the community level [9, 11]. Coherent implementation of climate resilience at the grassroots level is important in Chile to address the significant disaster and climate change risks [13], as well as the hydrological changes associated with climate change which pose major risks to the country's development [14–16]. For example, the integrated management of socio-ecological systems in central Chile will be crucial for reducing the impacts of drought and forest fires on livelihoods and food security in the face of climate change [14,17,18]. However, there is a significant research gap on resilience in central regions of Chile [17].

With the understanding that climate change impacts have already been observed [19], it is more important than ever to understand how resilience initiatives are implemented at the local level. Therefore, this research applied an empirical mixed-methods approach to examine the context-specific barriers to the implementation of climate resilience at the grassroots level in the Araucanía Region in central-southern Chile.

2. Background

Extreme weather events, disasters, and the failure to effectively mitigate and adapt to climate change are key risks faced globally [20]. Changes in weather extremes attributable to anthropogenic warming since 1950 are already detectable and are expected to increase as anthropogenic emissions continue to cause long-term climatic changes [19]. Risks posed by these increasing climate-related hazards have greater impact in countries with higher rates of exposure and vulnerability, particularly in the Global South [21].

In the last two decades there have been increasing calls for coherent implementation of DRR, CCA/M and sustainable development [1, 22–24]. This has somewhat been driven by improved knowledge regarding the short- and long-term implications of climate change in the context of extreme weather events [2]. The convergence of goals and timeframes of international policies has also contributed, including: the Sustainable Development Goals, Sendai Framework for Disaster Risk Reduction, and the Paris Agreement on Climate Change [1,24]. Coherent approaches aiming to combine the implementation of several objectives of different international agreements can have positive co-benefits which enhance impact and outweigh the negative trade-offs [25]. Ensuring adequate implementation of these approaches through climate-resilient development pathways has become an increasing focus in recent years [2,19].

Resilience is a key underlying factor for dealing with gradual and sudden change; it incorporates the ability to prepare for, absorb and recover from acute or chronic adverse events [26–28]. It also includes the concept of adaptive change and evolving to an improved state, sometimes referred to as 'bouncing forward' [28,29]. In the context of this research, climate resilience is seen as an opportunity for a more systemic, cross-cutting approach to DRR and CCA/M [30] and is considered as an attribute of sustainable development [31] (Fig. 1).

Climate-resilient development pathways incorporate CCA/M and DRR which focus on reducing negative impacts of climate change in the context of sustainable development [2,19]. Within the context of this research, DRR is defined as approaches "aimed at preventing new and reducing existing disaster risk and managing residual risk" [p. 16, 32].

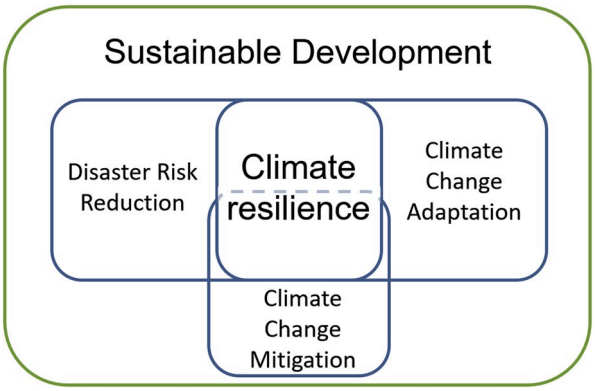

Fig. 1. Conceptual framework of climate resilience (figure by authors).

CCA refers to the "process of adjustment to actual or expected climate and its effects" [p.542, 19]. Both DRR and CCA contribute to climate resilience by reducing the impacts of climate change and safeguarding sustainable development [19,32]. CCM, referring to the "human intervention to reduce emissions or enhance the sinks of greenhouse gases" [p. 554;19], contributes to development pathways and climate resilience by reducing risks presented by climate change and contributing to technological development in line with national CCM and sustainable development policies [2]. Examples of CCM actions that were considered in this research include, environmental action to contribute to conserving or restoring biodiversity and ecosystems (including municipal policies on field burning practices and reduction of the use of environmentally harmful chemicals), and implementation of renewable energy systems (including the implementation solar panels for emergency energy supply).

Local level implementation of climate resilience, with the community as a critical element, has been stressed for several reasons. The community level is where climate change and disaster impacts are most apparent, and where solutions are most urgently needed [7,9,11]. However, traditional top-down approaches have had limited success in realizing grassroots resilience [8]. Local government officials and their proximity to community stakeholders is particularly important for engaging the community and addressing their priorities to enhance chances of long-term sustainability [9,12]. Furthermore, this is said to be the level at which synergies and trade-offs between various policies most commonly materialize in relation to climate change [9,11]. The importance of local DRR plans are reflected in Target E (increase the number of countries with national and local DRR strategies) of the seven global targets set out by the Sendai Framework [32,33]. However, the Sendai Framework has been criticized for providing little guidance for implementing the international goals on the local level [34].

2.1. Implementation barriers for climate resilience

Significant barriers to implementing climate resilience at the grassroots level have been reported worldwide, including limited financial resources, technical capacities and human resources, and information on specific climate change risks at useable scales [35–39]. However, the DRR and CCM literature lacks synthesis of barriers to grassroots implementation (e.g. Refs. [14,40–46]). Comparatively, numerous attempts have been made to track national progress on the implementation of CCA and consolidate the literature on the associated barriers (e.g. Ref. [4,8,9,35,47,48]). While these barriers are commonly organized into conceptual categories, they exist in complex, dynamic systems which interact across scales [44,49]. As such, these barriers are often co-dependent and interrelated [49] and occur at different stages in the adaptation process [39].

Similarities between barriers to the implementation of DRR and CCA/M are evident in the literature. Commonly cited barriers include

socio-political barriers such as governance and coordination across multiple sectors and scales [40–46,50]; and resource barriers including inadequate disbursement of funding, technical and human resource capacity, and knowledge and information [3,39–42,49,51]. Furthermore, DRR and CCA/M literature both emphasize the necessity of community engagement, and incorporation of local knowledge and priorities in planning to facilitate implementation [9,12,34,52–54]. However, it is well known that implementation at the grassroots level, and the existing barriers to this process, are highly context-dependent [4,8,47]. In-depth empirical research is needed to deepen the understanding of such barriers [4]. As such, this research sought to answer the following question: *What are the key barriers to the implementation of climate resilience at the grassroots level in the Araucanía Region in central-southern Chile?*

2.2. Status of national policies in Chile

Chile is one of the world's ten most vulnerable countries when it comes to climate change [13]. The central-southern region of Chile (30–48°S) is crucial for agriculture. It houses a large portion of the population and faces well-documented climate-related hazards. As climate change progresses, central-southern Chile will experience precipitation decrease and temperature increase, which will result in increased drought and fire risks [14,15,17,18,55–58]. Anthropogenic emissions, including radiative gases like carbon dioxide and methane, have been identified as contributing to 25% of the experienced precipitation decline and recent mega drought [55]. As climate change continues, extended droughts are expected to become more frequent, with these conditions representing the future climate [17].

A number of national policies are in place in Chile to build resilience to climate change and the associated risks [59,60]. Chilean national DRR and CCA/M polices make frequent references to the SDGs, Sendai Framework and Paris Agreement. Furthermore, coherence between sustainable development and climate resilience is acknowledged in national and regional policies. The policies emphasize the importance of mainstreaming DRR and CCA/M into national and regional development plans and recognize DRR as an important component of CCA/M and sustainable development [59–62]. Both national plans for DRR and CCA/M highlight the need to strengthen national institutional frameworks and mechanisms for implementation [59,60].

Previous research in Chile indicates limited implementation of DRR and CCA/M at the local level. A case study of northern Chile conducted in 2007 found that despite the significant advances in disaster management in Chile, local level implementation requires significant strengthening [63]. More recent research identified low levels of DRR implementation at the grassroots level in most Latin American countries, including Chile [64]. This is further supported by the reporting process for the Sendai Framework, which reveals that coverage of DRR at the local level remains low, with less than 30% of local governments having a DRR plan in 2017 [65]. This indicates that there are significant barriers to grassroots implementation in Chile. Institutional fragmentation in regional governance has been identified as a barrier to urban CCA in the city of Santiago [49]. However, there is a need for more research on the implementation of climate change policies in Latin American countries [66]. Furthermore, research on climate resilience in central regions of Chile remains scarce [17], with a clear need for in-depth empirical research on implementation barriers.

3. Methods

This research applied an empirical mixed-methods approach to examine the context-specific barriers to the implementation of climate resilience at the grassroots level in the Curacautín area located in the Araucanía Region of central-southern Chile. Qualitative data included key informant interviews and Focus Group Discussions (FDGs). Quantitative data was collected through community questionnaires, and historical climate data on rainfall and temperature.

Semi-structured key informant interviews were conducted with 22 experts from the national, regional and municipal governments, non-government organizations (NGOs) and academia. These interviews provided in-depth insight into the barriers to implementation from the national to the local level. Representatives at the national and regional level included those from Ministries related to: urban planning and development, water and sanitation, emergency response, and the environment.

FDGs provided insights into community priorities in relation to climate change and disaster risks. These were conducted with community members from the following five communities in the Curacautín area of the Araucanía Region: Captrén (n = 3), Curacautín (n = 12), Santa Julia (n = 4), Rari Ruca (n = 19) and Santa Ema (n = 14). The FDGs followed on from a dissemination workshops of the community risk assessment conducted by the Centre of Environmental Sciences (EULA-Chile).

A thematic analysis was conducted for the qualitative data using an inductive approach with the support of NVivo 12 [67]. Key commonalities and differences in the expert interviews and FDGs were identified. Based on this, emergent themes were openly coded and compared using comparative analysis tools (e.g. matrixes). A second round of coding allowed for the refinement of themes and sub-themes.

The quantitative questionnaire for community members (Appendix A) was designed to provide insight into community perception of climate change and disaster risks, as well as perceived responsibilities for addressing these risks. In May 2018, a pilot study of 73 questionnaires was conducted in local community risk workshops with volunteer participants, and the questionnaire was adapted accordingly. The sample size (n) for quantitative questionnaires was calculated using the formula for finite populations. The population (N) was defined by those older than 18 years, either male or female, residing in the Curacautín study area. A proportion of 50% and a precision of 5% were used [68]. Initially 385 surveys were obtained from community members. For reasons of loss or rejection, it was necessary to apply 18% more questionnaires. Finally, 454 valid questionnaires were obtained in May and June 2018. Respondents were selected using proportional sampling, in relation to the total population of the seven communities in the Curacautín study area (Fig. 2). The final questionnaire covered individual and demographic characteristics, perception of the evolution of climate-related natural hazards, level of climate change knowledge and awareness, responsibilities in terms of implementation, and community willingness to participate in DRR and CCA/M.

Of the 454 community members who completed the questionnaire, 61% (n = 277) were from urban Curacautín. The remaining 39% (n = 177) were from rural towns, including: Captrén (n = 30), Malacahuello (n = 35), Manzanar (n = 35), Rari-Ruca (n = 27), Santa Ema (n = 25) and Santa Julia (n = 25). The comparison of the demographics of the questionnaire participants and the populations, according National Census and CASEN 2017 [69,70], can be found in Table 1.

Finally, climate and hazard data was collected for the 1990–2016 period to compare with survey results relating to community perception of changes in climate-related hazards (Appendix B). Temperature and precipitation data were collected from the Centre for Climate and Resilience Research [71]; forest fire data was collected from the National Forestry Corporation [72]; drought was calculated using the Standard Precipitation Index over three month intervals [73]; flood data was collected from DesInventar Sendai [74] and Rojas et al. [16]; records of landslide data from DesInventar Sendai [74] and SERNAGEOMIN [75] were combined.

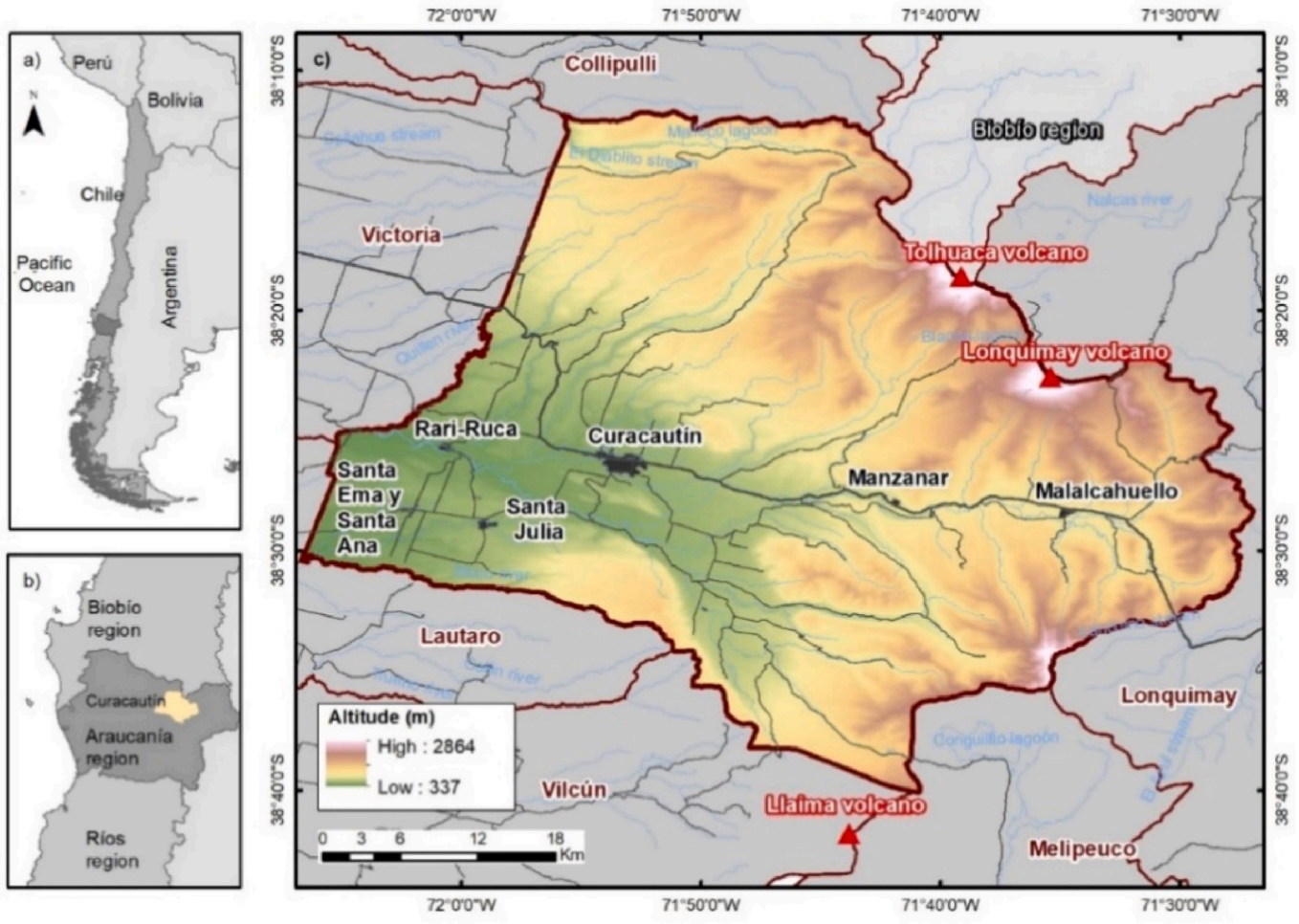

Fig. 2. Study area . a) Map of South American context; b) Chile context; c) Map of Curacautín and study areas with topographical variations by Digital Elevation Model Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER-GDEM) (figure by authors).

Table 1
Comparison of demographics of study sample and population.

Demographic	Questionnaire sample	Population characteristics of the Curacautín area
Age (Years)	52 ± 16.2 (19–94)	49.3
Female	40% (n = 180)	52%
Female (household)		39%
Education		
Education (Total years)	10 ± 3.7 (1–22)	9.3
No Education	4% (n = 19)	5%
Basic level of education (up to 8 years)	32% (n = 146)	36%
Attended secondary school	48% (n = 217)	41%
Attended university	15% (n = 69)	16%
Employment Status		
Gainfully employed	39% (n = 177)	46%
Full-time head of household	35% (n = 158)	12%
Studying	4% (n = 18)	5%
Retired	17% (n = 79)	25%
Unemployed	4% (n = 16)	12%

Table 2
Example quotes from expert interviewees on community awareness and knowledge.

Topic	Example quote from expert interviewee
Low levels of community understanding of climate change risks	"People don't understand climate change, they don't have the capacity to make relationships between temperature changes, rain intensity/ frequency, etc. There is also a poor knowledge of natural resources."
Community capacity to address risks	"People don't have all the information they need in that matter and if they get it, it is often not understandable by them … There needs to be more practical training and more real participation of the locals so they can get knowledge."

4. Results and discussion

4.1. Socio-political factors

4.1.1. Governance

Governance challenges were the most pertinent barriers discussed by experts. Key governance challenges related to a lack of prioritization of climate resilience with respect to other national priorities, limited vertical and horizontal coordination between implementing actors, and a centralized decision-making structure with limited authority delegated to regional and municipal administrations. Experts highlighted the crucial role of the national government in establishing the framework and coordinating mechanisms for resilience. They identified community and municipal governments as key actors with shared responsibility in building resilience. As one NGO representative stated:

"We need DRR to focus more on community resilience."

There is a clear demand from community members and experts at all levels for stronger government presence and capacity in the systematic implementation of climate resilience. The municipal government was highlighted as a crucial missing link in strengthening community resilience by both experts and community members. Experts highlighted the restructuring of the National Office for Emergencies (ONEMI) as an opportunity to provide greater autonomy and funding to the municipal government. This is particularly important as the majority of community members (69%, n = 291) believed the municipal government has the main responsibility for implementation (Fig. 3). FDG participants in both rural and urban areas also supported this finding. Over half of community members viewed themselves and civil society as having a secondary responsibility (53%, n = 209), with less than a third of respondents (28% n = 117) stating that individuals and civil society have the primary responsibility.

The national government has made a commitment to implementing climate resilience specifically with a "decentralized perspective" [76]. Furthermore, the national policies designate responsibilities to the regional government through the Regional Climate Change Committee and Regional Offices of ONEMI [59,60]. The present research suggests a clear need to increase local-level governance. A large body of literature supports the need for enabling institutions at both local and national levels [9], with similar governance challenges in other settings [10,42,43]. Two common governance challenges identified by Piggot-McKellar et al. [8] are highly relevant to the Chilean context: 1) lack of relevant government departments at the appropriate scale, and 2) poor vertical coordination.

4.1.2. Multi-sectoral approaches

An integrated multi-sector approach to land use management and planning was considered crucial for achieving sustainable development and reducing risks, at the same time, experts recognized that this is a critical barrier to implementation. Experts described a shift towards a planning-oriented approach that emphasizes long-term sustainability and includes CCA/M and DRR. They suggested strategies (e.g. sustainable urban planning, reforestation and watershed management) that balance the needs of communities, the environment and economic sectors (e.g. tourism, agriculture, and mining). This also included the need to integrate scientific knowledge into decision-making, and supporting researchers to strengthen the link between research, policy and practice. This has been further demonstrated by the establishment of the Scientific Committee on Climate Change in April 2019 to support policy implementation towards the nationally determined contribution [77]. However, experts noted that multi-sectoral approaches are not yet the norm and there is a dire need for stronger regulations.

Multi-sectoral coordination can potentially improve the implementation of climate resilience [3,4,40]. Coordination across sectors will likely maximize co-benefits and synergies to achieve Chile's desired development outcomes [78]. For example, integrated management of socio-ecological systems could facilitate better management of the growing drought and forest fire risks in Chile [14,17,18]. However, this research illustrates that multi-sectoral coordination is a barrier to developing coherent cross-government approaches to climate resilience. This is supported by similar findings from CCA research in Santiago [49] and from other settings [54,79,80]. Strengthening national and regional coordination mechanisms was recently identified as a priority for addressing climate change risks in Chile [81]. However, it is also important to ensure effective multi-sectoral coordination at the local level [11,52–54], and ensure the local level is well connected to regional and national governance structures.

4.2. Resource factors

4.2.1. Misconceptions around community knowledge

Expert interviewees identified low levels of community climate change knowledge and awareness as one of the most prominent challenges to implementing grassroots DRR and CCA/M. In contrast, the results from the survey and FDGs suggest high levels of community knowledge and awareness. These results represent a clear misconception among experts about community climate change awareness and concern, presenting a barrier to meaningful community engagement in implementation.

In general, experts emphasized the need for a greater understanding of climate change risks at the community level. As such, experts identified strengthening community awareness and education as a key leverage point for effective participation in building climate resilience. Some interviewees identified the need to build community capacity to address the climate change and disaster risks. Table 2 highlights example quotes illustrating these points. Additionally, experts spoke of communities and municipal planners forgetting disaster experiences and exhibiting "amnesia", highlighting that awareness of risks does not guarantee long-term planning at the municipal and regional levels.

Comparatively, the survey indicated that the majority of community members in the Araucanía Region clearly perceived climate change as affecting their community (91%, n = 409), with 37% (n = 163) and 32% (n = 141) rating climate change as important or very important. When self-reporting on their level of climate change knowledge 71% (n = 322) of the community reported they had some knowledge and 10% (n = 47) stated that they knew a lot. Supporting this, the majority of survey participants (86% n = 386) indicated that human activity is the main driver of climate change. Community members also recognized that their localities face disaster risks, with 44% (n = 198) reporting that their community faces some level of risk and 23% (n = 102) reporting their community faces a high level of risk. FDG participants indicated that community climate change concerns exist in relation to other social concerns, such as livelihood security, education and health. For example, farmers discussed the fact that the quality and quantity of their harvests are declining, and noted substantial vegetation loss due to drought and high summer temperatures.

Additionally, the survey results indicated that large portions of the

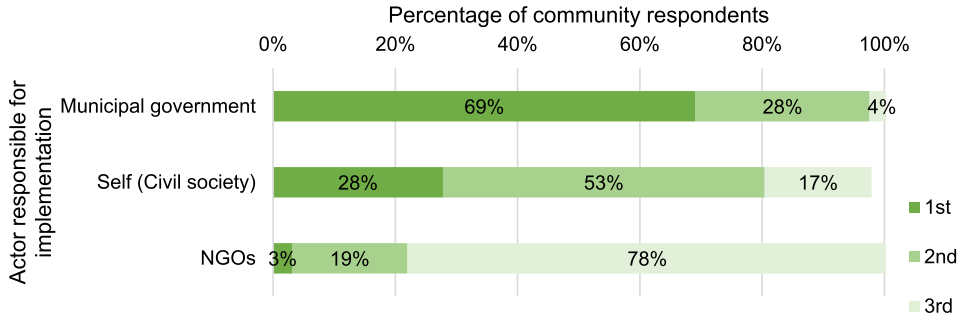

Fig. 3. Perceived actor responsibility for implementing DRR (figure by authors).

community correctly perceived a change in several climate-related hazards (Fig. 4). Community members perceived an increase in the intensity of temperatures in summer (76% n = 342) and winter (83%, n = 376). Scientific research projects temperature increases for central Chile under the RCP8.5 scenario[1] [17]. The historic climate data supports increases in the average maximum summer temperature for the Region (Appendix B). Precipitation decreases were correctly observed by 54% (n = 244) of survey participants. The precipitation decreases in central Chile is evidenced by climate change research [17,55] and supported by the historic climate data (Appendix B). Community members (64% n = 287) correctly perceived the increase in droughts, which is evident in the Araucanía Region [56] and has been partially attributed to anthropogenic climate change [15,55]. The increase in forest fires was clearly and correctly perceived by 49% (n = 221) of survey participants. Increases in forest fire risk in central-southern Chile have been linked to drought conditions [14,17,18] and are expected to continue to increase due to climate change and environmental stressors from land use [14].

Importantly, this research identifies a misconception held by experts about community climate change knowledge and awareness. These results illustrate that there are high levels of community climate change awareness and concern, which is also supported by the Chile national climate change survey [82]. This disparity between levels of community knowledge and experts' expectations of community knowledge merits further investigation, particularly in light of the limitations of self-reported methodologies for assessing climate change knowledge. Furthermore, it is important to acknowledge that this research was conducted less than six months after the January 2017 wildfires in Chile, which potentially plays a role in the level of community concern around climate change. Additionally, community members correctly perceive changes in temperatures and droughts, supported by previous research on farmers in central Chile [83]. Community engagement and participation in DRR and CCA/M are crucial for successful implementation [3,9,11,40,52–54]. However, this is potentially hindered by the misconception that the community are not aware of, or concerned by, climate change, which does not appear to be the case in this study region in Chile.

Including community knowledge and priorities into national policies to ensure climate resilience policies are responsive to local needs [4,8,9]. Differences between expert and community risk perceptions have previously been identified [84,85]. Policymakers have a responsibility to address risks in a meaningful way for community members, and ideally build on their own initiatives or projects [86]. These results illustrate that community concerns for climate change risks often occur in the context of other social concerns. This highlights the opportunity to mainstream CCA/M in the context of broader development concerns, particularly as investments in sectors supporting climate resilient development (e.g. health and social security) have higher potential for scale-up compared to disaster management and education-based CCA [19].

4.2.2. Financial and human resources

Experts stressed that insufficient allocation of financial and human resources were key barriers to implementation, particularly at the municipal level. Several experts associated funding challenges with the predominant short-term thinking and response focus of the national DRR system, as opposed to a long-term vision of risk prevention. The need for greater allocation of financial resources was reinforced by the community survey where almost all survey participants (97%, n = 435) believed the municipal government should dedicate a portion of its budget to DRR.

Recent commitments have been made to strengthen resources for CCA at the regional levels [81] and the national DRR plan emphasizes the importance of community-based DRR [60]. However, little detail is provided regarding the required human resources or funding mechanisms for municipal and regional governments. This was supported by expert interviewees, as a municipal official stated:

> "When the municipalities have little funds there is little we can do. We survive with what we have … We try to do what we can to garner support where we can. The government says it is concerned but at the same time they don't give us the money to do something. What are your priorities?"

In terms of human recourses, having adequate manpower and technical capacity at the appropriate scale were key concerns for interviewees. Technical capacity is needed for assessing and understanding local risks, effectively transferring knowledge and information to the local level, municipal planning for climate change and disaster risks, and preparedness for both acute and slow-onset hazards. An expert in natural risks stated the following:

> "There are some good ideas but to implement them you need to get the public administration involved at the local level which is a real challenge. There is no understanding, people have different priorities and people very often don't have the right background. There is no knowledge about management of hazard and risk mitigation."

The community showed a high level of willingness to contribute to

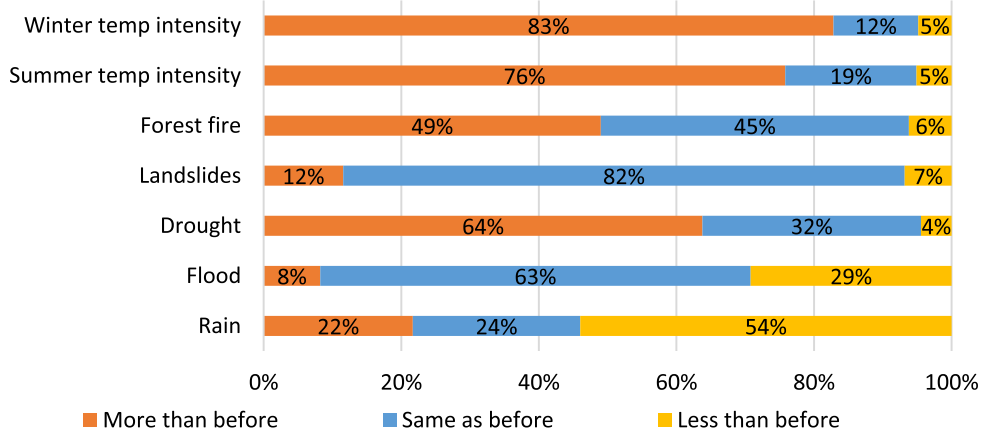

Fig. 4. Community perception of the evolution of climate-related hazards (figure by authors).

[1] A scenario of high greenhouse gas emissions assuming high population growth and relatively low CCM efforts.

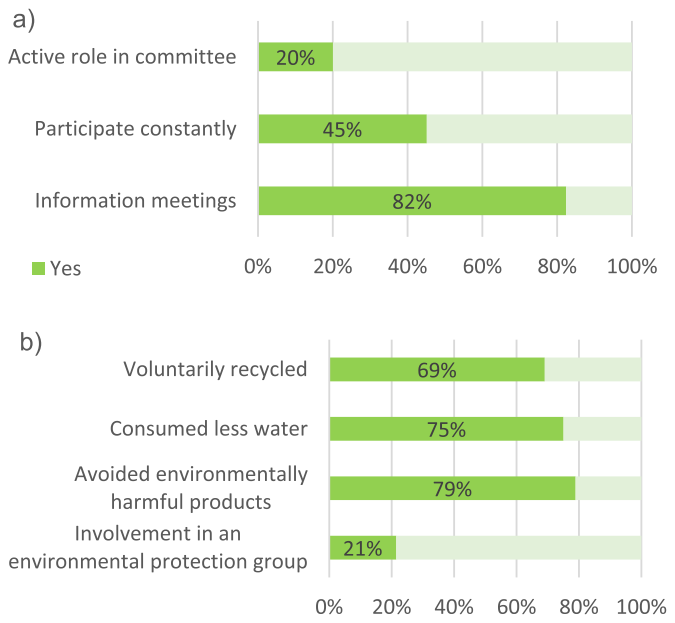

Fig. 5. *Community member willingness and contribute to local action* a) Willingness to participate in various DRR activities; b) Contribution to environmental initiatives in the last year.

DRR. The survey indicated 84% (n = 378) of community members are willing to contribute in some capacity to local DRR. Of these, 82% (n = 374) stated that they would be willing to attend information meetings, just under half (45%, n = 205) would be comfortable contributing on a continual basis and 20% (n = 91) would be willing to take on a permanent role in a local DRR committee (Fig. 5a). Of those willing to participate in an ongoing manner, most indicated that they would be willing to contribute one day (38% n = 77) or two days (36% n = 72) a month, with an average of 2.67 days per month.

The community also indicated high levels of willingness to participate in environmental action that contributes to CCA/M. For example, 90% (n = 393) said they would be willing to participate in the Municipality's 'Recycle, Repair and Reuse' program. When asked about their involvement in environmental action in the last year, 21% (n = 97) stated they were involved in an environmental protection group, 79% (n = 355) avoided environmentally harmful products (e.g. pesticides), 69% (n = 310) voluntarily recycled and 75% (n = 337) tried to consume less water (Fig. 5b).

The willingness of community members to contribute to DRR and CCA/M represents a potential opportunity to strengthen implementation at the local level. Community motivation and commitment can potentially enhance grassroots implementation of climate resilience [87]. As indicated by previous research in Chile, community organizations and networks are important contributors to CCA [78,88] and a key factor related to municipal expenditure on DRR [89]. However, community willingness needs to be supported by appropriate financial, human and technical resources, which are currently lacking. As identified by Piggott-McKellar et al. [8], the disbursement of resources for CCA is heavily impacted by inadequate coordination between governance structures, and are closely related to technical capacity at the local level. Providing adequate financial and human resources for improving long-term climate resilience should be viewed as an investment and opportunity to leverage community resources to improve social and economic development [53].

5. Conclusion

The need to strengthen grassroots implementation of DRR and CCA/M in the Araucanía Region in Chile persists. Implementation progress is limited by complex socio-political and resource barriers. More specifically, these implementation barriers include fragmented horizontal and multi-sectoral governance, and inadequate allocation of human and financial resources at the local level. Most importantly, a misconception held by experts relating to community climate change knowledge and awareness presents a significant barrier to grassroots implementation. As long as community awareness of climate change and disaster risks is not recognized, the opportunity for leveraging community willingness to act will be missed. Perceiving the community as a passive entity with limited awareness of the risks they face impedes the incorporation of community knowledge and priorities into national policies. Furthermore, recognizing existing levels of local knowledge and awareness is crucial to target capacity building at the correct level and ensure a focus on developing capacity for action.

Governance of the coherent implementation of DRR, CCA/M and sustainable development represents highly complex, multi-level processes. This poses challenges in terms of linking international agreements to the national, regional and local levels and ensuring that the most appropriate and effective measures are implemented at the right level. Using high levels of climate change awareness as a leverage point for community-level resilience action is only possible if national actors coordinate more closely and recognize the importance of the municipal level in implementing international and national policies. In doing so, policymakers need to provide adequate support to municipal governments and allocate the appropriate financial and human resources. National and regional actors must also work closely with municipal governments to mobilize synergies and leverage impactful collective action at the grassroots level. Ultimately, these implementation challenges are crucial in how climate change can be tied to the implementation of international agreements, including the SDGs, at the grassroots level.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

Funding: This work was supported by the Swiss Bilateral Research Programs: Leading House for the Latin American Region, Seed Money Grant 2017 [SMG1710]. The authors would also like to thank Joaquín Alejandro Gajardo Castillo for his help collecting the historical climate data.

Appendices A and B. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijdrr.2020.101703.

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