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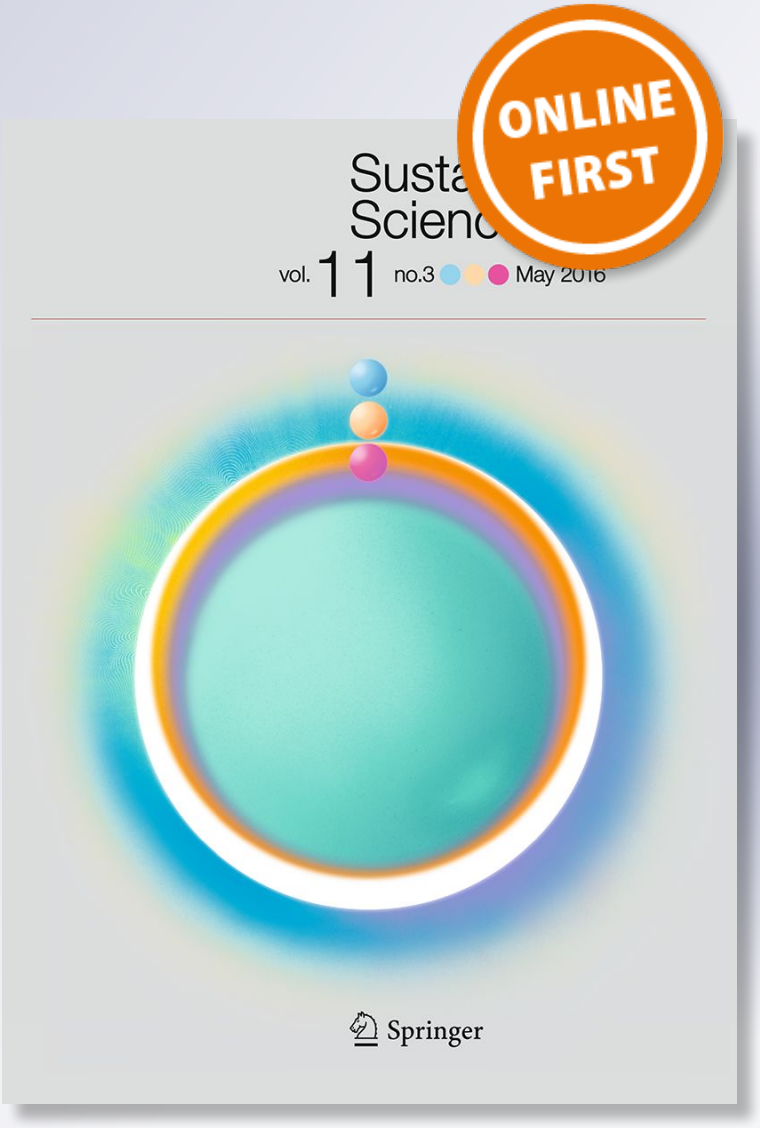

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ORIGINAL ARTICLE

On the evaluation of adaptation practices: a transdisciplinary exploration of drought measures in Chile

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Abstract

A severe drought has affected central Chile since 2009. Various adaptation responses have been developed, and a participatory process is required to learn from them. To enable this, a transdisciplinary approach was adopted to achieve two objectives: first, to test an approach for assessing the effectiveness of existing measures to respond to drought, specifically to distil strengths and weaknesses of implementation, and developing recommendations; second, to reflect on results from a pilot project conducted to ascertain its potential for scalability in terms of processes employed. The research was organized per the three types of knowledge needed to address complex problems through transdisciplinarity: systems, target and transformation knowledge. Using the recent drought as a boundary object, we conducted the pilot in two locations in Chile where we carried out literature reviews, interviews and focus group discussions were carried out. We identified adaptation measures at national and local scale, a set of which were evaluated applying the Index for the Usefulness of Adaptation Practices (IUPA). Results indicate that through IUPA, we could systematically account for the perceived effectiveness of applied measures. Strengths such as autonomy in the decision-making process emerged as key factors that could also be applied in other contexts, whereas weaknesses such as lack of integration with other policy domains, programs or projects were identified. To address weaknesses, key recommendations were proposed, which are congruent with context-specific expectations, capacities, experiences and knowledge, given that they were articulated by local actors. Results present empirical evidence on the important utility of transdisciplinary approaches in the evaluation of adaptation measures and can support the development of metrics related to adaptation process at the local scale.

Keywords Evaluation of adaptation · Drought · Resilience · Index for the Usefulness of Adaptation Practices (IUPA) · Transdisciplinarity · Chile

Introduction

In recent years, there has been a growing tendency to generate government plans, programs and scientific publications on climate change adaptation, yet little is still known about the real effect of these adaptation measures in society, their utility or success (IPCC 2014). The IPCC

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(2014) also notes that addressing climate change has been restricted to characterization of impacts, vulnerability and adaptation planning and measures, with little effort focused on the evaluation of the implementation and effects of the latter. Moser (2015) argues on the need to develop indicators for adaptation in order to improve monitoring and evaluation of adaptation processes, yet warns that these indicators can end up being unused, invalid, unfunded or even unknown, hence advising to use a "small set of meaningful, purpose-driven and decision-relevant indicators" (Moser 2015:1).

Generally, methods for ex-post evaluations of adaptation measures include cost–benefit analysis, cost-effectiveness analysis and multi-criteria analysis (PROVIA 2013). The first two perform the assessment in terms of monetary values, while the latter focuses on relative weighting of different metrics or variables based on the subjective determination of success in strategies and measures to achieve planned objectives (UNFCCC 2011). This type of analysis involves the development and use of economic, environmental and social criteria, among others (Klein and Tol 1997) and allows the identification of weaknesses and strengths of each of the options based on the criteria used for the evaluation (UNFCCC 2011). Multi-criteria analyses have been developed and applied through different tools, such as Analytic Hierarchy Process or AHP (Bhushan and Rai 2014; Saaty 1987), the Index for the Usefulness of Adaptation Practices or IUPA for its acronym in Spanish (Aldunce et al. 2008), MCA4climate (UNEP 2011), the software M-MACBETH (Cox et al. 2013) and the CYPADAPT multi-criteria analysis tool (CYPADAPT-Project 2013).

Arnott et al. (2016), after surveying an important number of indicators and metrics for the evaluation of adaptation, conclude that these evaluation practices are still relatively recent in the climate change adaptation context and, therefore, may not have yet reached its full potential. Even though there have been important advances in the evaluation of adaptation, there seems to be a focus on the research of adaptation goals instead of adaptation processes, and efforts are still needed to develop evaluation practices that are feasible, yet robust. This is relevant in order to improve adaptation options and make a more accurate characterization of their success according to the effect on stakeholders, trade-offs involved, and the recognition of the importance of the context (Arnott et al. 2016; Mimura et al. 2014). Improving these processes at local scale will contribute towards building metrics that effectively help identify factors that describe strengths and weaknesses of adaptation measures and, hence, those factors that support change in the long term (Mimura et al. 2014). All of this is important in order to "avoid underestimating the complexity of adaptation as a social process, and creating unrealistic expectations in societies" (Mimura et al. 2014:890).

These studies reinforce a call for greater interaction between experts and users in evaluation measures, ensuring "scientifically defensible and practically relevant" evaluation results (Arnott et al. 2016:9). This call also promotes a paradigm that reflects a transdisciplinary approach, which is seen as part of a social process that makes explicit the underlying values and norms in society and in science, thereby attributing meaning to scientific knowledge for societal purposes (Hirsch Hadorn et al. 2006:121). In this context, we believe that more efforts should be done at local scale so knowledge can be co-produced with those actors that actually put adaptation into practice. In this way, practices can be made more robust, but can also extend the application of this knowledge outside the scientific domain, facilitating the link between science and society and hence addressing the inherent complexity of climate change. Through these types of processes, it is possible to create a virtuous cycle, where scientists provide local actors with scientific knowledge that is not only more precise and accurate, but also more 'socially robust' (Gibbons 1999).

In this paper, we present the results of a pilot study aimed at testing an approach for assessing the usefulness of existing drought measures, specifically to distil strengths and weaknesses to implementation, as well as proposing recommendations for improving identified weaknesses. This evaluation also served to reflect on the pilot in terms of the process and results in order to up-scale the experience. This paper continues with a description of the case study from where our results emerge ("Case study background"), followed by the methodologies employed to systematize information and evaluate the adaptation measures ("Methodology approach for the pilot phase"). We conclude the paper with a discussion on results generated ("Results and discussions"), lessons learnt and suggestions for moving forward ("Conclusions").

Case study background

The broader project

This study was developed in the context of a broader project, which consisted of two phases: a pilot phase to test the approach (the study presented here) and a second phase where the methodology received feedback from the pilot and then applied at a larger scale. This broader project was based on transdisciplinarity as the research paradigm for investigation. A transdisciplinary approach involves a process of co-production of knowledge that accounts for the diverse perspectives of actors affected by complex

Table 1 Research questions of the broader project, the types of knowledge (S: system; Ta: target; Tr: transformation) represent the methods used to address each one of the research questions. Source: Own elaboration based on the type of knowledge from Pohl and Hirsch Hadorn (2007)

Research question of broader project	Type of knowledge	Methods
What are the adaptation measures conducted in Chile?	S	Document review
		Consultation with experts
		Interviews
How useful are these measures?	Ta	Focus group discussions
How can they be improved, and what are the weaknesses for their implementation from a practitioners' perspective?	Tr	Focus group discussions

problems such as impacts of climate variability and change. Finding solutions to complex problems requires the integration of three types of knowledge (Pohl and Hirsch Hadorn 2007:38): (1) What is the present situation or phenomena under investigation, and the interconnected factors and actors/processes involved in its possible development and interpretation (system knowledge); (2) What is the ideal situation or what do actors aspire to in the future, considering the diversity of their norms and values (target knowledge); and (3) How to learn from past and current experiences in order to change and achieve these targets, considering different options for change, such as technical, social, legal or cultural factors (transformation knowledge). For the purposes of this project, we sought to account for these three types of knowledge in the evaluation of adaptation measures to address drought in Chile (see Table 1). The methods used in this broader project included document reviews and related thematic content analyses, consultation with experts, interviews with local actors and focus groups discussions (FGDs). This multi-method approach emphasized participatory processes to support co-production of knowledge for building resilience to climate change.

The design of this project includes a pilot phase to test the methodologies and processes to be able to answer the research question of the broader project. The focus of this paper is on documenting lessons learnt from the pilot phase.

Ground-truthing: the pilot study

Given its magnitude and impact for Chilean society, we focused our attention on the Chilean mega drought (Garreaud et al. 2017) as a 'lived experience' or boundary object to understand the impacts of drought in context. A boundary object in the context of climate extreme events (Lynch et al. 2008) can be a meaningful means to understand complex climatic conditions, such as the manifestation of an extreme event, as perceived by a diverse set of actors with different backgrounds. The mega drought, the most extensive registered in terms of space and time (Garreaud et al. 2017; Boisier et al. 2016; CR2 2015), has affected diverse productive sectors in central and southern Chile. For example, in 2014, the General Water Directorate (DGA) declared 41 counties[1] with severe water shortage (DGA 2014). Moreover, during the 2010–2011 summer season, water reserves reduced to a third of normal capacity, "leading to water levels 45% below historical averages" (Sánchez et al. 2012:452), which in turn negatively affects hydroelectric power generation. Drought impacts were also repeatedly reported in the media. For example, the national newspaper *La Tercera* published an article titled 'Gone with the drought' (Acevedo and Derosas 2014) where different stories regarding drought along the central regions of the country were told, emphasizing its spatial extend. Additionally, the Ministry for Agriculture declared 194 counties under 'agricultural emergency' (MINAGRI 2015), meaning that agriculture activities in those counties were threatened because of water deficit, most of them in the central area of Chile. Finally, the National Institute of Statistics (INE 2013) reported that many agricultural yields showed a negative trend due to drought conditions, for example, cereals, legumes and industrial crops (non-food/non-feed products) showed either reduced area of production or yields. Furthermore, Boisier et al. (2016) stated that a quarter of the current drought in central Chile can already be attributed to anthropogenic climate change. Several studies of climate projections indicate a robust drying trend for the region (Bozkurt et al. 2018; IPCC 2013). More specifically, Bozkurt et al. (2018) project that droughts of similar magnitude and frequency can be expected in the future, highlighting even more the need to closely evaluate not

[1] The word 'county' (*comuna* in Spanish) is used to refer to the smallest administrative division applied in Chile, whose management is in charge of a municipality, followed by provinces, regions and national level.

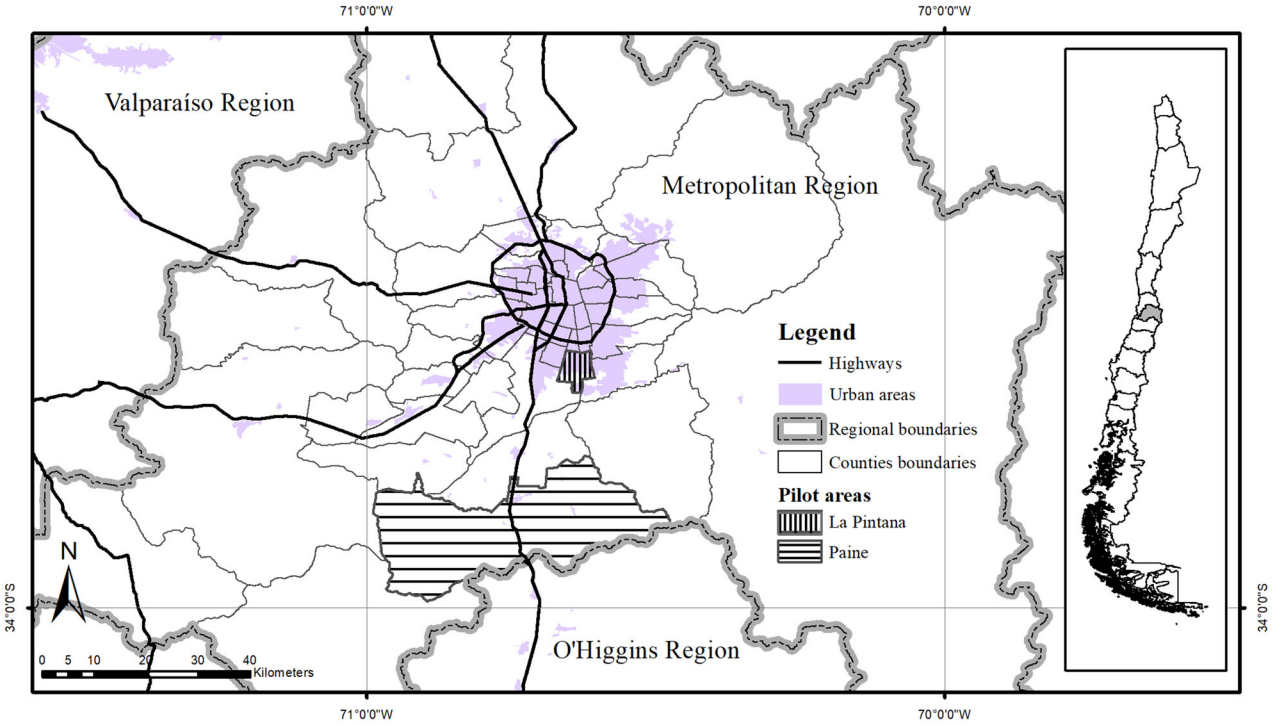

Fig. 1 Location of the counties of the pilot study

only measures in place to adapt but also the processes involved.

In order to pay a closer look at the effectiveness of drought adaptation measures in practice, two pilot studies were conducted. These pilots were selected using the following criteria: (1) need, interest and will of public practitioners to collaborate in order to address an existing problem of drought as expressed by them; (2) access to information and key actors. According to these criteria, two counties of the Metropolitan Region were selected: La Pintana (urban) and Paine (peri-urban) (see Fig. 1).

La Pintana is an urban county located in the southern sector of the city of Santiago and has an estimated population of 212,656 habitants (BCN 2015a). Though it does not present rural inhabitants, 1.7% of its economically active population is employed in agriculture, which is the second highest among the counties of the city of Santiago (Berdegué et al. 2010). It is characterized by the presence of different industries, densely populated areas of 6211.9 hab/km^2 according to Berdegué et al. (2010), as well as small domestic farms, representing an interface between Santiago and other rural counties. La Pintana's inhabitants face relevant social issues. For example, they have a population density index of 27.94, which is higher than the national average of 19.88 (BCN 2015a), and 17.01% of its population is considered 'poor' according to levels of income, which is also higher than the national average of 14.40% (BCN 2015a).

Paine is a peri-urban county located to the south of the Metropolitan Region, beyond Santiago city boundaries, with an estimated population of 66,855 habitants (BCN 2015b), 36.8% of whom live in rural settlements, and with a density of 73.8 inhabitants per km^2 (Berdegué et al. 2010). Its main centre is the town of Paine and is characterized by its agricultural activities that provide food to Santiago, with 34.8% of its population employed in the sector (Berdegué et al. 2010). Additionally, there are industries from different sectors and recreational areas with native vegetation. Paine has a population density index of 19.45, lower than La Pintana and very similar to the national average of 19.88. Levels of poverty according to income reach 16.70% of its population (BCN 2015b), which, as the case with La Pintana, is high compared to the national average of 14.40% (BCN 2015b).

Methodology approach for the pilot phase

The process of the study was in four steps, detailed in Fig. 2, and explained in the following paragraphs.

In step 1, we identified actors related to drought events in Chile (which can be consulted in Aldunce et al. 2015b) in terms of their role in managing water resources, the direct impacts to their activities, or other interests in the subject. Actors considered for the study included the

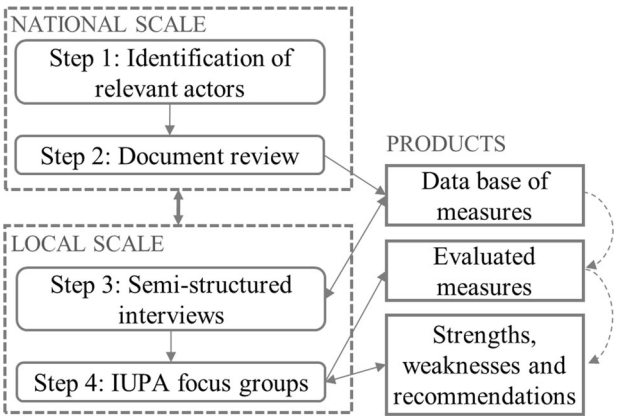

Fig. 2 Process followed to conduct the research

scientific community, public sector, civil society and private sector (based on Cornell et al. 2013).

With the identification of actors as a starting point, step 2 was to track actions that these actors had taken in response to the drought or drought measures, through a systematic review of documents focusing on the time period between 2009 and March 2015 and geographic regions between the Region of Coquimbo and the Region of Araucanía. Responses were systematized in a data base (which can be consulted in Aldunce et al. 2016) that contained detailed information of each document, such as name of organization, period of time, geographic location, source of information, type of measures, and productive sector of application, among others. We collected a total of 146 measures, which are summarized in Table 2.

For the evaluation of adaptation measures, we needed to work with local actors. The main rationale for selecting local actors, in a joint process of assessment and evaluation of drought measures, is that they are more knowledgeable about their own community context, which also facilitates a political process for collective action that, according to Lynch and Brunner (2007), is much easier to achieve at this local scale. Therefore, a key element for achieving social learning is to allow local actors to make their own decisions about which factors, indicators, criteria and desired outcomes should be taken into consideration in an assessment and evaluation framework of what has worked (or not) for them (Brunner 2014). This helps to identify transformation knowledge that translates into 'better' measures in accordance with local circumstances, and not simply replicating models of 'best measures' applied elsewhere that are often devoid of the context and mechanisms under which they were rendered successful (Brunner 2014). This level of deep, intensive and comprehensive case study-based approach allows a look into how these enabling mechanisms work in context, a window into a 'microcosm' for how we may learn from and transfer or up-scale knowledge across cases and contexts (Adler et al. 2018; Brunner 2014; Brunner and Lynch 2010; Lynch and Brunner 2007).

To address local scale, steps 3 and 4 were carried out. Step 3 consisted of a total of 30 semi-structured interviews, of which 17 were conducted in La Pintana and 13 in Paine, allowing us to collect locally relevant measures and thereby complementing the database. The selection of interviewees was done with the goal of accounting as much as possible for the diversity of actors and realities of the case study. A non-probabilistic stratified sample was used, applying purposive and snowball techniques, in order to identify and incorporate key actors with specific characteristics relevant to the investigation (Hernández et al. 2010). Purposive sampling is a non-probabilistic sampling technique and is dependent on the criteria and expert judgment opinion of the investigator for participant selection (Neuman 2006; Subban 2009).

Interviews addressed the following topics: basic information from the interviewee (type of actor, age, organization, etc.); measures carried out to face drought (what was its objective, when was it implemented, who implemented it, what does the measure entail, how was it funded, etc.); as well as other actors involved (contact information of other actors that could be interviewed).

Step 4 consisted of a participatory evaluation process to assess a non-probabilistic sample of measures, gathered through the aforementioned interviews. The selection of measures to be evaluated was based on the expert judgement of the research team, procuring to maintain the diversity of measures regarding their sector and types of actor, and concluded with the evaluation of 12 measures, six in Paine and six in La Pintana. These evaluations were was carried out in two meetings, one in La Pintana, with 14 participants, and one in Paine, with 20 participants, where the Index of Usefulness of Practices for Adaptation (or IUPA for its acronym in Spanish) was applied through FGDs. The selection of participants was based on the information provided by interviewees, the date of discussion set to favour the attendance of interviewees and other relevant actors as they suggested and procured to maintain diversity.

The IUPA is an example of a method of multi-criteria assessment. This index is a flexible tool that integrates different variables, allowing users to evaluate the usefulness of adaptation measures and to compare them. Weights and scores are assigned to a set of evaluation criteria defined by the users, after which the individual criterion scores are aggregated into a single index value (Debels et al. 2009). The variables eligible by users were: Participation of the target population; Relevance; Pertinence; Continuity over time; Flexibility and/or robustness; Efficacy or achievement of goals; Efficiency (cost-effectiveness); Equity; Degree of environmental protection; and

Table 2 Summary of measures found through documents' review and pilot studies, according to the percentage of presence in three features: type of users, type of measures, and productive sector. Source: Complete database is available in Aldunce et al. 2016

Feature	Source			
	Doc. review (%)	Paine (%)	La Pintana (%)	Total (%)
Type of users				
Public sector	59.80	21.80	55.30	48.50
Private sector	21.50	41.80	26.30	28.00
Civil society	12.10	36.40	18.40	20.00
Scientific community	6.50	0.00	0.00	3.50
Productive sector				
Agroforestry	29.10	30.40	51.10	32.40
Sanitation	12.20	22.80	36.20	18.20
Recreation	6.60	7.60	10.60	7.40
Hydropower	8.90	4.30	2.10	6.80
Education	8.50	5.40	0.00	6.50
Other	7.50	7.60	0.00	6.50
Mining	5.60	4.30	0.00	4.50
Biodiversity	5.60	4.30	0.00	4.50
Industrial	5.60	4.30	0.00	4.50
Type of measures				
Engineering and infrastructure	20.50	29.20	51.00	29.60
Initiative of the population	0.90	43.10	29.40	18.90
Instrument of economic development	20.50	1.50	0.00	10.70
Legal mechanism or institutional arrangement	12.80	9.20	2.00	9.40
Training/education/awareness	8.50	7.70	13.70	9.40
Plans/programs/management	14.50	0.00	0.00	7.30
Project technological innovation and research	10.30	0.00	0.00	5.20
Technical assistance and technology transfer	6.80	3.10	3.90	5.20
Delivery of goods and supplies	4.30	4.60	0.00	3.40
Other	0.90	1.50	0.00	0.90
Total	51.40	24.70	24.00	100

Articulation of the measures with policies, programs and/or projects (for more details see Carrasco 2016).

This tool also allows capturing the subjective components of a complex issue such as climate change. At the same time, it provides a clear framework to allow participants to engage using a common guide, which does not require large groups to facilitate deliberation. The sample size is justified given the in-depth reflections from key actors, thus capturing relevant context specificities. The combination of this tool, cross-referenced and complemented with a broad search and review of drought measures at national scale (step 2) and interviews with local actors (step 3), provides inputs necessary to account for context in the interpretation of results obtained through the application of the IUPA.

The process to evaluate the measures promoted participation of the different actors that attended the workshop. The workshop started with a plenary session where variables were explained by a member of the research team, and participants were given time to resolve doubts about them. Later, the IUPA method was applied in focus groups of 5–10 persons, each of them facilitated and assisted by two research team members. The evaluated measures were explained by a group member that had applied the measure or had adequate familiarity or experience with it, after which the remaining of the group members had the opportunity to questions and clarify different aspects of the measure. Then, the group discussed which variables should be used to evaluate the explained measures in particular, the relevance each variable had for that particular measures (weight) as well as the variable's performance (score). This resulted in a consensual range for the scores and weights for each variable used to evaluate the measures. Blind voting took place afterwards by each group member individually, evaluating the measures on a sheet of paper, and indicating specific scores and weights without the influence of the group's suggestion. This procedure was repeated for each evaluated measure. At the end of the meeting, a

plenary was carried out to discuss the variables that represented weaknesses for the measures' execution, and how they thought it was possible to address and improve them in the future.

Results and discussion

The measures (system knowledge)

Results show that almost half of the 146 collected measures (Table 2) are implemented by public sector actors, almost one-third by private actors and a quarter by civil society. In Paine, however, measures led and implemented by the private actors and civil society are more dominant with 41.8 and 36.4%, respectively, which is a consequence of the relevance of local scale organizations and farmers in rural areas, as well as the direct impact of droughts on their day-to-day activities.

About a third of the measures are concentrated in the agroforestry sector, a self-evident result given the sector's dependence on irrigation to sustain its productivity. These results are consistent with findings reported in the assessment of the National Climate Change Plan (Aldunce et al. 2014b) where great progress in terms of adaptation to climate change in Chile was found in this sector. The sanitation sector has almost a quarter of measures, representing a key sector for securing drinking water and, therefore, supported by public agencies, water companies and users, more notably at local scale. Conversely, other important productive sectors have less focus on adaptation measures, such as mining and industry (4.5%), and access to private sectors information is limited. Little attention has been paid to protect biodiversity from the impacts of droughts, as it only represents a 4.5% of the total collected measures.

Regarding the type of measures, almost one-third of all collected measures are in engineering and infrastructure, and linked to agroforestry providing irrigation infrastructure, such as canal lining and piping, construction of dams and reservoirs, and modern irrigation techniques that are of special relevance at local scale. From the bibliographic review, instruments of economic development stand out with a quarter of the total, which are mostly agricultural subsidies derived from drought emergency decrees, one of the most important public instruments applied by the State in serious cases of droughts. Fewer measures are dedicated to building resilience, for example, only 5.2% is dedicated to technology transfer and 9.4% to training, education and awareness. This is consistent with Parry et al. (2009), who state that measures focused on infrastructure, or 'hard' measures, can be easily implemented and transferred but have the potential to be more expensive than other measures that focus on institutional arrangements, or 'soft measures' (Parry et al. 2009:26). This difference is important given that 'hard' measures are often rigid, dependent on large technological systems and address only certain types of impacts, while 'soft' measures often involve flexible, small-scale and decentralized actions, building on "existing cultural norms to address local development concerns" (Sovacool 2011:1179).

Strengths and weaknesses for measures' improvement (target and transformation knowledge)

From the measures collected from interviews and bibliographic review, 12 drought measures were selected to be evaluated using the IUPA method, whose final scores are shown in Table 3.

Table 3 List of evaluated measures in pilot studies and their final Index for the Usefulness of Adaptation Practices (IUPA) scores

County	Measures	Final IUPA score[a]
Paine	Use of modern irrigation techniques	6.8
	Creation of Paine's assembly for water	6.7
	Intensification in the delivery of water with cistern trucks	6.6
	Well deepening	4.5
	Feeding of the Aculeo lagoon through the junction with an irrigation channel	3.5
	Restriction of the Paine aquifer for new allocation of groundwater rights	3.3
La Pintana	Use of less demanding trees in municipal green areas	7.3
	Water efficiency at home	7.3
	Educative workshops to neighbours of a building complex	7.1
	Pedagogical exhibition of a rainwater collector	6.5
	Maintenance of irrigation channels	6.4
	Turning of fire hydrants to avoid waste of water	3.4

[a]Scores go from 1 to 10, where 1 is not useful and 10 is very useful

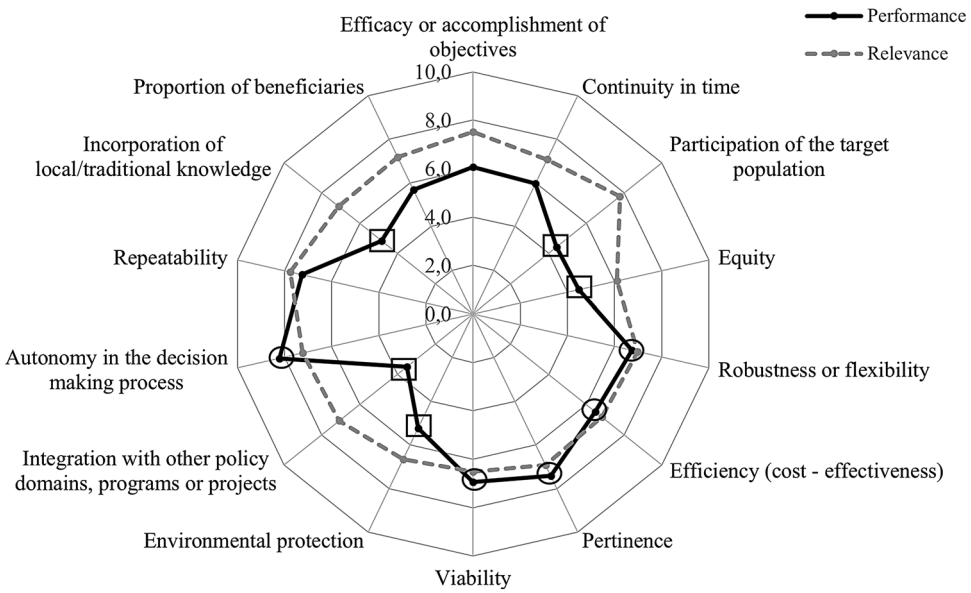

Fig. 3 Radial chart with the performance (in the solid line) and relevance (in the dashed line) of each evaluated variables. The circles represent the most important strengths identified in the meetings (higher performance scores) while the squares represent the most important weaknesses (lower performance scores)

During the focus groups, fourteen variables were used to evaluate each measure; figure shows a summary of the scores and weights obtained for each of these variables, highlighting those with the highest and lowest scores that represented strengths and weaknesses, respectively, of the evaluated adaptation measures in Paine and La Pintana. It is important to note that the process used to assign weights to different variables within the IUPA was confusing for participants in the focus groups, we consider this limitation important as a redesign factor for the scaling up to the broader project.

The circles in Fig. 3 represent the most important strengths identified in the meetings: autonomy in the decision making process; viability; pertinence; efficiency (cost-effectiveness); and robustness or flexibility. These strengths are relevant for illustrating the conditions under which these measures are perceived to be effective, which is the key information for transferability of these measures into other contexts.

The squares in Fig. 3 represent the most important weaknesses identified in the meetings: integration with other policy domains, programs or projects; participation of the target population; Incorporation of local/traditional knowledge; environmental protection; and equity. These weaknesses represent the unfulfilled expectations that actors have of key strengths that measures should have but are deficient.

In general, these weaknesses are similar to those registered in the literature in California, where we can find strong similarities to the Chilean case, regarding climate and geographical conditions, the occurrence of a severe multi-year drought, and even in the emphasis on 'hard' measures. For example, literature shows a need to improve measures so they address their potential social and environmental externalities, considering vulnerable groups (Christian-Smith et al. 2015; Van Loon et al. 2016), and the importance of measures that are integrated with other policy domains (Tortajada et al. 2017).

Weaknesses identified through IUPA are important to consider because they point towards key target knowledge of what is envisaged as ideal in addressing droughts impacts (transformation knowledge). For this reason, we elaborate on the following five most significant weaknesses.

First, the integration of the measures within other programs is relevant because it enables mainstreaming, ensuring consistency and synergy with national and local priorities (Aldunce et al. 2012; Rodríguez et al. 2013) and hence avoid incongruences and overlapping work. For example, Tortajada et al. (2017) elaborate in the extent of measures that have been needed in California to cope with an extreme event, such as a multi-year intense drought, requiring the coordinated effort of different sectors and actors, which, according to their findings, has been key to appropriately react to the event.

Second, actors emphasized the need to increase participation of the target population, concurring with what is largely stated in the literature (Bird et al. 2011; Haque and Etkin 2007; Norris et al. 2008; Pfefferbaum et al. 2007). Participation is important because of many reasons, for example because communities represent a valuable and unique source of knowledge that is based on their experiences in dealing with droughts, which depend on their specific physical and social context (Bahadur et al. 2010; Brunner 2014; O'Brien et al. 2010). Furthermore, communities that confront impacts of drought have an innate

knowledge of what works and what does not work in responding to droughts (Aldunce et al. 2015a), requiring meaningful participation that goes beyond a consultation processes alone.

Third, equity represents a cross-cutting issue when it comes to climate change (Clément et al. 2015; Okereke et al. 2014) and is important because inequitable development limits the potential for present and future well-being of communities. Therefore, adaptation measures should be designed in such a way to protect particularly vulnerable groups and reduce the negative externalities that can affect other groups (Adger et al. 2005; McKenzie Hedger et al. 2008; Okereke et al. 2014). Inequitable measures can aggravate current inequalities and, hence, fail to fulfil their objective. This weakness is also recognized by Christian-Smith et al. (2015:10), in California, where they studied the impacts of drought measures taken in the agriculture and energy sectors, concluding that, even though measures were able to maintain water supply in the short term, they also "led to increased vulnerability of ecosystems and social groups that rely on those ecosystems for their health or employment".

Fourth, traditional and local knowledge can be useful to better understand local phenomena and their processes (Brunner 2014; Jones et al. 2015; Reyes-García 2015). However, it is often disregarded when it comes to local planning design (FAO 2004; Reyes-García 2015), leaving aside important aspects of the local context that can impact on the implementation of a measure (Aldunce et al. 2014a). In this regard, traditional and local knowledge represents an important input that contextualises scientific knowledge, thereby enhancing validation between science and local communities (Gibbons 1999).

Finally, fifth, environmental protection is relevant for climate change, as it is a major challenge for the development or selection of adaptation measures that do not affect the environment (Aldunce and Debels 2008; Brown 2011; Eriksen et al. 2011; Smit et al. 2000). In this sense, it is desirable for adaptation measures to at least represent no-regret actions (Martin 2012). In line with these findings, Van Loon et al. (2016) affirm that infrastructure-based measures taken in California, such as water storage in reservoirs and groundwater abstraction, can have relevant environmental impacts, such as the exacerbation of drought and depletion of groundwater levels. These findings concur with responses deliberated in the focus groups regarding the deepening of wells and the implementation of irrigation technologies.

It is interesting to note how some of these weaknesses relate to closed knowledge system as defined by Cornell et al. (2013). For example, Cornell et al. (2013) mention that these systems reflect the following characteristics: substantially detached from society, politics and the media; self-regulated; organized in disciplines; and setting the research agenda autonomously. In this pilot, those characteristics have the potential to emerge due to weaknesses identified such as integration with other policy domains, programs or projects; participation of the target population; and incorporation of local or traditional knowledge. Cornell et al. (2013) argue that closed knowledge systems have "restricted ways of engaging with societal demands for knowledge and in societal discourses, but generally on its own terms and through intermediaries", limiting the capacity for institutionalizing transdisciplinarity approaches (Cornell et al. 2013:66). If this is true, overcoming of identified weaknesses could also contribute to transform closed knowledge systems into open knowledge systems and effective knowledge arenas, hence facilitating transdisciplinary processes.

Closing the implementation gap: recommendations (transformation knowledge)

Participation throughout the evaluation processes allowed assistants to engage in all the evaluation stages and, thereby, promoting social learning, seen as "the co-production of knowledge arising from the engagement of multiple knowledge producers" (Cornell et al. 2013:63). The co-production was archived by sharing experiences and opinions and allowing the proposal of recommendations for improving adaptation measures and their implementation processes. These were discussed by the participants and the research team and are shown in Table 4.

The focus group offered a unique platform to share experiences and knowledge, along with making explicit the opinions of local actors, which are often not considered, even though they seem to be evident. Hence, these recommendations represent a systematization and integration of new co-produced knowledge that support transformation knowledge. It will be important in the future to analyse if these recommendations have been implemented and how useful they were.

Other observations and results obtained

We could witness first-hand how this process of evaluation also served as a platform for exchange of opinions, experiences and points of view between participants, which can boost social learning and hence reinforce the adaptation process. For example, in this pilot, participants acquired insights into adaptation measures that they were unacquainted with, while they gained awareness of possible negative consequences in their implementation. To systematically account for this learning process, it will be important to develop tools that allow registering those

Table 4 Weaknesses identified through the Index for the Usefulness of Adaptation Practices (IUPA) method in the pilot studies and recommendations derived from the participative discussion in the meetings

Weaknesses	Recommendations for improvement
Integration with other policy domains, programs or projects	To seek for creating synergies with other policies and projects, and between agencies
	To highlight the issue of drought as a crosscutting issue
	To enhance local leadership and formal tools for local environmental management
Participation of the target population	To incorporate the population in the measures' cycle and decision-making
	To enhance participatory processes
	To enhance local media for dissemination of information
	To sensitize and educate about drought thematic
Equity	To plan and make decisions based on vulnerability assessments
	To promote proactive versus reactive measures
	To strengthen (formal and informal) local organizations
Incorporation of local/traditional knowledge	To generate platforms for social learning
	To decentralize generation and use of information
	To strengthen action research and transdisciplinarity
	To rescue, preserve and value local knowledge
	To maintain effective and permanent channels of communication
Environmental protection	To include mitigation, compensation and reparation measures for the negative impacts of measures
	To change the anthropocentric approach towards the environment
	To raise awareness
Cross recommendations	To plan realistic and appropriate deadlines, human and economic resources
	To promote value systems that include empathy, solidarity, environmental protection and respect for cultural, social and age diversity
	To disseminate information to the population that allows achieving access symmetry among different actors in respect of the specific impacts to which they and the environment are exposed

elements that participants recognize as new learning. The use of surveys and other tools to account for and capture these social learning processes would be the key to test in the broader project, so that we can better document the extent of transferability of knowledge from this case to another case as a target, and state clearly the conditions under which the learning took place.

Conclusions

In this paper, we present important evidence that supports the advancement of both theory and practice of evaluation and improving climate change adaptation. Adopting a transdisciplinary approach allowed us to jointly evaluate adaptation measures with actors involved in their implementation, making a concrete contribution to improve bottom-up adaptation in Chile, and to bridge the gap at the interface between science and policy. The combination of the IUPA with a transdisciplinary approach proved to be a powerful tool to address the complexity of a wicked problem such as climate change.

Our results show that there is a diversity of measures implemented in Chile by different actors to respond to droughts in the context of climate change, with a focus on 'hard' measures over 'soft' ones, which can hinder social aspects of adaptation processes. Using the IUPA, we found that these measures have differentiated usefulness, depending on what is valued in a specific context. More specifically, what participants of the pilot study valued are represented by the IUPA results as strengths and weaknesses in the implementation of adaptation measures. The most significant strengths are autonomy in the decision making process; viability; pertinence; efficiency; and robustness or flexibility. Identification of these strengths is relevant as conditions for transferability of these measures for potential application and adaptation into other contexts.

The most salient weaknesses focused on: integration with other policy domains, programs or projects; participation of the target population; incorporation of local and traditional knowledge; environmental protection; and equity. We infer that these weaknesses represent key characteristics that measures should have, but, from their perspective, are deficient. These weaknesses are important to consider because they embody the values that underpin desired outcomes (target knowledge), which form the basis for co-designing solutions to address drought impacts (transformation knowledge). These results are important

lessons when considering the implementation of measures into other contexts, and to avoid creating unrealistic expectations.

To improve these weaknesses, participants proposed key recommendations; some of them are cross cutting issues to all weaknesses, while others are specific for each one of them. Given that these recommendations were articulated by local actors themselves, it is assumed that they are congruent with context specific expectations, capacities, experiences and knowledge and, therefore, if taken into account, they are more likely to be actually implemented in the future. This is consistent with Cornell et al. (2013:62), who argue for the "development of new skills, tools and procedures that support the co-existence of multiple knowledge systems… in adapting social learning to meet the pressing challenge of sustainability". This way, these recommendations represent a relevant opportunity not only for the improvement of measures but also of public policies, serving for the triangulation of national scale strategies with local scale implementation of adaptation options. The challenge about these recommendations is to incorporate them into decision-making processes, which needs a great deal of communication and deliberation efforts and follow-up.

With regard to methodological enhancements, four key lessons emerged: first, the need to improve the process of assigning weights to different variables within the IUPA, which was deemed confusing by participants in the meetings. Second, to send the IUPA user's guide to participants prior to the meetings, so they are able to review it beforehand and become familiar with the terms and processes involved. Third, engagement with people during the interview process is fundamental to get them participating in the focus groups; this should increase the number of participants and increase representativeness of sectors for the application of the IUPA. However, it is important to note that the focus of this approach is also to account for in-depth dialogues between actors, where reflections of the nature and origin of weaknesses can emerge, which can be hindered in bigger groups. Finally, fourth, social learning needs to be better captured as part of the process of knowledge co-production, not just in the context of the content matter being addressed (droughts), but also on the processes, environments and conditions that facilitated this learning and sharing, which could be accomplished through the use of surveys and other tools.

Finally, we also noted that focusing on a concrete boundary object enabled participants to demystify climate change as an external distant phenomenon, instead relating it to concrete impacts associated with droughts that are expected to be more frequent and severe under a changing climate. This grasping of the climate change problem at a human-scale has also the potential of a wider impact, related to behavioural changes required to address climate change (de La Fuente et al. 2017).

Having shown the strength of this transdisciplinary approach, through a multi-criteria evaluation methodology (IUPA) for a specific phenomenon (drought), constitutes a valuable contribution towards the evaluation of the implementation and effects of adaptation measures on climate change, helping bridging the gap between science and policy. It can, therefore, provide guidance and development of metrics related to adaptation processes at local scale that can be implemented and up-scaled.

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