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"*We are responsible for deciding how we, as farmers, influence political decisions*": adaptation practices to droughts by small-scale farmers in a globally important South American Archipelago

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Introduction: In the current context of global environmental change, small-scale farming systems are being negatively affected by various social-ecological change processes, including climate variability, the occurrence of extreme events, and other anthropogenic pressures. In these circumstances, droughts represent one of the main challenges for small-scale farmers, as they directly affect their production, farming systems, and livelihoods.
Methods: Through a qualitative approach, we identified the main adaptation practices implemented by these farmers and based on them, we collaboratively developed recommendations to address climate variability among small-scale farmers in the northern part of the Chiloé Archipelago, a territory recognized as a Globally Important Agricultural Heritage System (GIAHS) in southern Chile. To this end, we conduce 20 semi-structured interviews with small-scale farmers and organized one focus group discussion that also included representatives from State agencies.
Results: Our results identified 30 adaptation practices to droughts. Most of these practices (66%) are autonomous (i.e., reactive actions to change that emerge from local knowledge), followed by mixed-origin practices (27%), and State-planned responses (7%). Additionally, through community-based prioritization of adaptation practices, we propose six recommendations for the development of local strategies to confront droughts, emphasizing how critical is to strengthened adaptive capacity of small-scale farming systems.
Discussion: Our findings highlight the importance of incorporating local knowledge, which is often marginalized during public policy formulation. This local and situated knowledge should be a key axis for the co-production, collaboration, and community empowerment in the adaptation of

GIAHS, in a context of increasing social-ecological changes. These insights offer valuable implications for governance, suggesting that inclusive, bottom-up approaches to climate adaptation can enhance the resilience and sustainability of small-scale farming systems in the face of ongoing environmental change.

KEYWORDS

adaptive capacity, Chile, Chiloé, climate change, climate variability, livelihood vulnerability, social-ecological systems

1 Introduction

Small-scale farming is an ancient activity deeply rooted in the culture and livelihoods of Indigenous Peoples and Local Communities, who have developed complex and generally adaptive production systems in response to changing conditions (Altieri, 1999). Globally, between 50 and 70% of food is produced by small-scale farmers, with one-third coming from farms smaller than two hectares (Lowder et al., 2021). In Latin America, 80% of farming holdings are of this type, playing a crucial role in the supply of staple foods and being fundamental to the livelihoods and food sovereignty of rural communities (FAO, 2014). For instance, this group produces nearly 100% of the potatoes and cassava in Bolivia, around 70% of the beans in Brazil, and 54% of the vegetables in Chile (Leporati et al., 2014). These farming systems reflect the strong relationship between human communities and local ecosystems and can thus be understood as social-ecological systems (SES) (Neves et al., 2017). In recent years, the rate of transformation of these systems has increased significantly as a result of Global Environmental Change (GEC), a concept that encompasses climate change, biodiversity loss, erosion of knowledge, resource overexploitation, and other social-ecological changes (Trenberth et al., 2014; Caviedes et al., 2023; Scheidel et al., 2023; Oyarzo et al., 2024b). Small-scale farming is highly dependent on the resource systems in which it is embedded; therefore, climate variability and anomalies have a direct impact on its development (Eitzinger et al., 2012; Campos Sánchez et al., 2013).

Climate variability refers to variations in the mean state and other statistics of the climate across all spatial and temporal scales, beyond individual weather events (IPCC, 2022). This entails an increase in the frequency and intensity of extreme events, such as droughts and frosts, which pose a significant threat to agricultural productivity (Seaman et al., 2014). In this regard, small-scale farmers are among the most vulnerable groups to the effects of climate variability, due to their historical marginalization and limited capacity to invest in prevention and recovery in the face of extreme events (Campos Sánchez et al., 2013; Milanés, 2021; Hagen et al., 2022).

Droughts, a specific manifestation of climate variability, represent one of the main effects of this phenomenon. They are characterized by prolonged periods of low precipitation and high temperatures, even in typically humid areas of the world (Trenberth et al., 2014; Vicente-Serrano et al., 2022). They occur when the availability of water resources is insufficient to meet human and environmental needs, resulting in negative impacts on the SES (Wilhite, 2000). Although the effects vary across regions, the most severe repercussions occurring in countries of the Global South (Easterling et al., 2007). The literature has documented various impacts of droughts on small-scale farming systems. In the state of Maharashtra, India, drought has driven processes of climate-induced migration, negative impacts on health and education, and has generated conflicts over water (Udmale et al., 2014). In Australia, extreme climatic conditions and reduced income during droughts have significantly worsened the mental health of small-scale farmers (Daghagh Yazd et al., 2020). In the Bolivian Altiplano, drought has caused losses of up to 50% in potato crop production, affecting food security (Camacho and Navarro, 2023). Similarly, in Pacific Islands and Territories, characterized as highly fragile ecosystems due to their insular condition, droughts increase the proliferation of pests and diseases, alter the nutritional content of crops, and erode local knowledge (Iese et al., 2021b).

To address this complex scenario, the Intergovernmental Panel on Climate Change (IPCC) established a conceptual framework to understand the vulnerability of SES. Within this framework, vulnerability is conceived as a three-dimensional concept that allows the identification of how exposed and sensitive to changes small-scale farmers are, as well as their capacity to adapt (IPCC, 2022). Adaptive capacity is the only dimension that can reduce levels of social-ecological vulnerability; therefore, strengthening it is essential (Negatu et al., 2011). Adaptive capacity is the process, action, or outcome within a SES aimed at confronting, managing, or adjusting to changing conditions (Adger, 2006; Smit and Wandel, 2006). Adaptations may be short-term, i.e. everyday actions resulting from individual or household decisions, or long-term involving social and ecological adaptation strategies based on collective decision-making (Berkes and Jolly, 2002). Likewise, adaptive capacity may be autonomous, referring to reactive measures based on local knowledge and resources; State-planned, involving strategic actions led by government authorities; or mixed, combining both approaches (Adger, 2006; Mersha and van Laerhoven, 2018; Aldunce et al., 2022).

Building on the above, it is important to understand the adaptive practices developed by small-scale farmers in response to droughts, as Indigenous Peoples and Local Communities frequently employ a diverse portfolio of strategies to cope with climate variability (Da Cunha Ávila et al., 2021; Schlingmann et al., 2021; Reyes-García et al., 2023, 2024). We understand practices as actions derived from spatio-temporal relationships among three components that must be coordinated: competence, meaning, and materiality. Competences involve the knowledge and skills necessary to carry out the practice; meaning refers to the elements that provide significance; and materiality encompasses the tools, infrastructure, and resources involved (Ariztía, 2017). Some examples include adjustments to the seasonal activity calendar, relocation of crops, exchange and incorporation of new seed varieties, livelihood diversification, water harvesting and management, and the incorporation of agroecology into productive systems (Zant et al., 2023; Hofstede, 2014).

However, the adaptation strategies employed by small-scale farmers do not always result in improvements for their productive systems, since individual capacities (e.g., a family's livelihood) that can drive adaptation are often constrained by structural limitations (e.g., governance and institutional support) (Rodríguez-Cruz et al., 2021). In these contexts, maladaptions (i.e., actions that, far from reducing vulnerabilities, end up exacerbating them) may also occur (Carmona et al., 2024). The foregoing underscores the need to evaluate the adaptation practices developed within small-scale farming systems. In this regard, the Adaptive Practices Utility Index (IUPA, its acronym in Spanish) has been established as a widely used participatory methodology (Lillo-Ortega et al., 2019). Various studies addressing variability and climate change employ this method, which is distinguished by its potential for the co-production of knowledge and subsequent formulation of territorially relevant adaptation strategies (Aldunce et al., 2021). As the effects of droughts exhibit unique characteristics in each region, there is no single adaptation strategy that is universally applicable and effective across different geographic areas (Acevedo-Osorio et al., 2017) and hence, contextualized responses based on farmers' local knowledge are needed. This highlights the necessity of addressing the issue through detailed analyses of specific cases, enabling the identification and contextualized use of local adaptations (Reyes-García et al., 2024). Likewise, while factors such as scientific knowledge, access to new technologies, and linkages with research centers and local governments may enhance adaptive capacity (Jellason et al., 2022), individual adaptive capacity alone does not suffice to address the social-ecological vulnerability. Therefore, it is key to design collective adaptation strategies of a local and participatory nature that integrate Indigenous and Local Ecological Knowledge (Rodríguez-Díaz et al., 2025).

In response to global trends threatening small-scale farming systems, since 2002 the FAO, together with various state governments, has identified different territories worldwide under the Globally Important Agricultural Heritage Systems (GIAHS) conservation initiative (FAO, 2018). Its objective is to recognize and safeguard sites of global significance, valued for their cultural, historical, and agricultural importance, linked to the maintenance of agrobiodiversity and the reservoir of local knowledge regarding the management of agrifood systems (Venegas and Lagarrigue, 2018). For example, the Andean Chakras of Ecuador GIAHS represent ancient terrace systems of the Kichwa Indigenous communities that have shaped a diverse landscape of high biocultural value (FAO, 2022).

However, designation as a GIAHS has not reduced the threats faced by small-scale farmers, as their livelihoods remain vulnerable to climate variability (Ducusin et al., 2019). Moreover, little attention has been paid to the social-ecological vulnerability of small-scale farmers within GIAHS, as well as to the understanding of individual and structural factors influencing their adaptive capacity (Oyarzo et al., 2024a). Since 2005, the FAO has designated over 100 GIAHS sites worldwide, including the Chiloé Archipelago, located in southern Chile (FAO, 2025). Small-scale farmers inhabiting this archipelagic territory have reported a notable reduction in precipitation, an increase in temperatures, and frequent drought events (Caviedes et al., 2023). These effects are exacerbated by the region's intrinsic geographic vulnerability due to its insular condition, as well as by political and economic pressures on key ecosystems (Reyes-García et al., 2022).

In this complex scenario, we conducted our research in the Chiloé Archipelago seeking to provide a bottom-up methodological perspective that contributes to improving the assessment and implementation of necessary measures to strengthen the adaptive capacity of small-scale farming in GIAHS of southern Chile. This study advances existing research on drought adaptation by moving beyond descriptive inventories of practices and by linking adaptation strategies to vulnerability, adaptive capacity, and participatory prioritization within a GIAHS context. We stress that the active participation of communities in the design and implementation of adaptation plans and policies enhances their adaptive capacity and improves their resilience to climate variability. Therefore, we aim to answer the question: How are small-scale farmers adapting to droughts, and which strategies are being prioritized at the individual and community levels to facilitate future adaptation? Our objective is to collaboratively develop climate variability adaptation recommendations based on the local practices and knowledge of small-scale farmers in an emblematic small-scale farming system of South America.

2 Materials and methods

2.1 Study area

Chiloé Archipelago is home to 176,865 people, 41% of whom live in rural areas. It is widely recognized for its long-standing tradition of small-scale farming, encompassing a variety of traditional practices rooted in the pre-Hispanic period and maintained over centuries by the Indigenous Peoples and Local Communities (INE, 2025; Cárdenas Álvarez and Villagrán Moraga, 2005). This territory is also acknowledged as a center of origin and agrobiodiversity hotspot for potatoes (*Solanum tuberosum*) at the global level (Solano, 2019). At present, small-scale farmers continue to engage in these agricultural practices, cultivating potatoes, homegardens, and fruit-tree orchards, raising livestock, and collecting forest and marine products (Venegas and Lagarrigue, 2018; Caviedes et al., 2024). These practices are supported by a farm-level water system that integrates various water sources and management methods, such as surface and groundwater. Additionally, collective Rural Drinking Water (APR, its acronym in Spanish) distribution networks exist, aimed at providing drinking water and managed by local committees with State support. However, due to the current water crisis, these networks are also being used for productive purposes (Frêne et al., 2022). Their infrastructure captures, stores, and distributes drinking water to communities not connected to urban networks, playing a crucial role in ensuring water access and addressing water scarcity (Alvarez-Garreton et al., 2023).

A growing wave of historical and contemporary social-ecological changes is severely affecting agriculture in the archipelago (Sapiains et al., 2019; Reyes-García et al., 2022; Caviedes et al., 2025). Although small-scale farming remains an important livelihood strategy in rural areas, the expansion of the aquaculture industry has contributed to the erosion of local knowledge that underpins agricultural production (Oyarzo et al., 2024b). Simultaneously, this industry generates seasonal employment for small-scale farmers, diversifying their income sources while also increasing their dependence on other productive activities throughout the year (Tapia and Marchant, 2025). In recent decades, the archipelago has experienced a significant shift in its climatic system, with more intense and prolonged droughts reported by the farmers themselves (Reyes-García et al., 2022; Caviedes et al., 2023). The region's hydrological regime is characterized by an annual precipitation of 1,890 mm, with peak rainfall occurring in July (https://explorador.cr2.cl). Between 1991 and 2019, interannual precipitation variability ranged between 9.8% and 15.5% (Oyarzo et al., 2024a).

Droughts occur during the summer months despite intense winter rainfall (Frêne et al., 2022). Although this phenomenon is rooted in atmospheric changes, its effects are exacerbated by anthropogenic activities on the archipelago. For instance, transformations associated with the logging of native forests, the establishment of exotic forest plantations of pines (*Pinus radiata* and *P. contorta*) and eucalypts (*Eucalyptus globulus*), the urbanization of rural areas, and the exploitation of peatlands through the extraction of sphagnum moss (bogs) have diminished the capacity of the island's hydrological system to conserve its water reserves (Zegers et al., 2006; Ther Ríos et al., 2018; Reyes-García et al., 2022). In particular, the municipal district of Ancud, home to 38,991 people, 27% of whom reside in rural areas, suffered severe consequences during the major 2016 drought, with small-scale farmers displaying considerably low levels of adaptive capacity compared to other areas of the region (Oyarzo et al., 2024a; Frêne et al., 2022).

2.2 Data collection

To examine adaptive capacity at the local level, we adopted a qualitative methodological approach using a case study strategy (Sampieri et al., 2014). We applied a non-probabilistic stratified sampling design and employed snowball selection techniques to identify and include key actors with specific characteristics relevant to the research, namely small-scale farmers aged over 18 who resided on their farms (Guest et al., 2006). The temporal scale of this research is anchored in a series of studies conducted over several years, building a trajectory of accumulated knowledge in the study area. Specifically, this research follows from a series of previous works (Caviedes et al., 2023, 2024, 2025; Oyarzo et al., 2024b) that have laid the groundwork for understanding the social-ecological dynamics of the region.

We conducted 20 in-depth interviews with small-scale farmers in the municipal district of Ancud (Figure 1). Additionally, we organized and facilitated one focus group discussion that included members of public institutions (5) and small-scale farmers (35) who had not been previously interviewed. The focus group discussion was developed within the framework of a collaborative agreement between the researchers and a self-convened territorial council (GIAHS Ancud Territorial Council). This council is composed of diverse actors from the agricultural sector, both women and men from Chiloé, who seek to promote a grassroots-based governance scheme for the GIAHS Chiloé. We obtained the free, prior, and informed consent from all participants, and the study was approved by the Ethics Committees of the Universidad Austral de Chile and the Pontificia Universidad Católica de Chile (protocol code 190603004–24 April 2020).

2.2.1 Semi-structured interviews

The interviews were conducted on each farmer's household (Figure 2), with the objective of identifying and analyzing the impacts of droughts on their livelihoods and the corresponding adaptation practices adopted by them. The interview was designed based on the atmospheric changes perceived by local communities in the study area and reported in Caviedes et al. (2023). These changes were mainly associated with the increasing frequency and intensity of droughts. In this regard, we investigated which practices are being implemented to adapt to droughts and their origin (autonomous, State-planned, or mixed), while identifying which type of climatic variability these practices are responding to: (I) intensity and duration of droughts, (II) intensity and timing of rainfall, (III) intensity and timing of temperatures, and (IV) seasonality of rainfall and temperatures.

2.2.2 Focus group discussion

After systematizing and analyzing the interviews and coordinating with the territorial council, we conducted one focus group discussion (Silveira Donaduzzi et al., 2015). The objective was to collaboratively evaluate the adaptation practices identified through the interviews. Based on this, we identified practices that participants prioritized to strengthen future community adaptation to droughts. To guide the discussion, we used as reference the core variables that comprise the IUPA (Aldunce et al., 2008). These variables are: (I) purposes of the adaptation practice, (II) duration of the practice implementation process, (III) total cost of the adaptation practice, (IV) level of autonomy in decision-making, (V) continuity of the adaptation practice over time, and (VI) level of resilience. These variables were used as qualitative analytical criteria to structure deliberation and collective reflection, rather than to compute a numerical index. It is worth noting that we did not seek to quantify this index; rather, we used its variables qualitatively to guide the conversation and discussion processes around the identified practices.

Focus group discussion took place in June 2024, during which farmers from the GIAHS Ancud Territorial Council were convened, and representatives from a public institution related to small-scale farming (Figure 2). This process involved 40 participants, including 35 farmers and 5 representatives from the Chilean National Institute for Agricultural Development (INDAP, its acronym in Spanish), with 27 women and 13 men, ranging in age

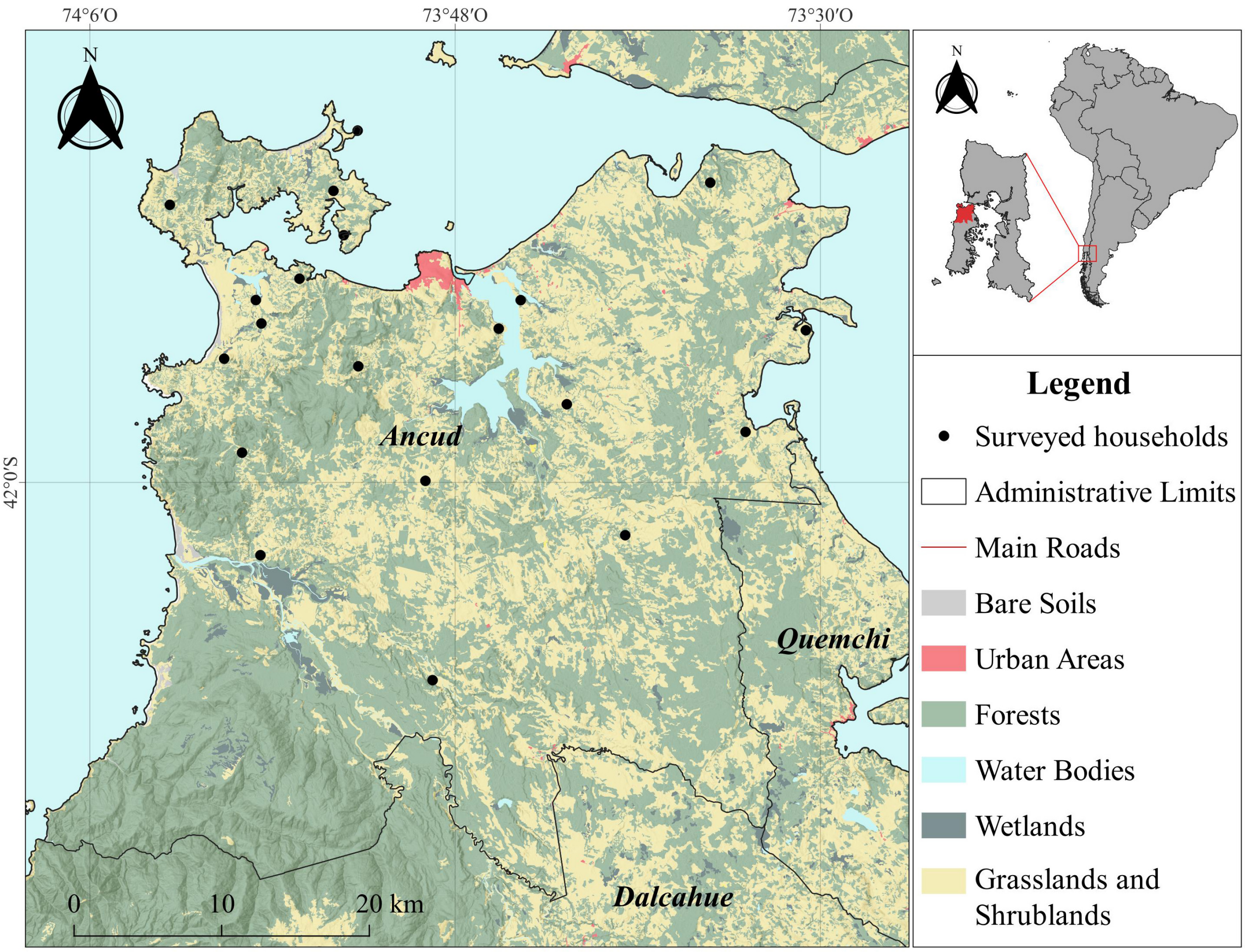

FIGURE 1
Study area and location of the 20 interviewed households in Ancud, a municipality in the Chiloé Archipelago, a Globally Important Agricultural Heritage System (GIAHS) in southern Chile.

FIGURE 2
Fieldwork. On the left, the development of a semi-structured interview is shown, on the right, the implementation of the focus group discussion. Source: Photograph by the Authors.

from 18 to 67 years. Participants were organized into four groups, each moderated by a member of the research team. Participants first reflected on the practices individually and then discussed them collectively in plenary sessions, allowing for comparison of perspectives and discussion of differences. The methodology consisted of providing each group with a set of adaptation practices reported in previous interviews.

These were used as a basis for dialogue to prioritize the practices and discuss their potential relevance for public policy formulation. The groups rotated between tables using the World Cafe methodology (Löhr et al., 2020). Before each rotation, participants rated the three most relevant adaptation practices based on the core variables of the IUPA, which enabled prioritization. Final prioritization was reached through plenary discussion and consensus, rather than through the aggregation of individual scores. At the end of the discussions, a collective synthesis of the outcomes was conducted. Subsequently, a group voting exercise was held, in which the identified adaptation practices were classified into three prioritization levels: low, medium, and high effectiveness. Practices consistently perceived as relevant, feasible, and impactful across the IUPA dimensions were classified as highly effective, those showing mixed assessments as medium effectiveness, and those considered limited in scope or applicability as low effectiveness.

Through this method, we were able to understand how adaptation is occurring, qualitatively assess the usefulness of adaptation practices from the perspective of local actors and decision-makers, and determine what adjustments are needed to sustain agricultural activities and rural life (Aldunce et al., 2008). Importantly, the participatory prioritization process provides insights that go beyond standard adaptation typologies or descriptive classifications. Rather than producing a static list of practices, the process enables the identification of those practices perceived by local actors as most relevant, feasible, and impactful for strengthening adaptive capacity. This prioritization serves as an analytical bridge between empirical evidence and the set of recommendations proposed in the manuscript, enhancing their interpretative depth and policy relevance.

2.3 Data analysis

Semi-structured interviews and focus group discussions were audio-recorded, transcribed verbatim, and analyzed through qualitative content analysis using ATLAS.ti 24 software. Following a mixed coding approach (inductive–deductive), the analytical process was conducted in three phases. In the first phase, deductive coding was applied based on the adaptation practice categories proposed by Schlingmann et al. (2021), which were organized according to seven adaptation domains. These domains represent the specific areas in which modifications are implemented, enabling a systematic categorization of the diverse adaptive responses of small-scale farmers (Table 1).

In the second phase, inductive open coding was conducted to identify emergent themes that were not captured by the initial categories, thereby allowing the identification of new dimensions and adaptive approaches. All authors participated in this phase, facilitating collective coding and discussing discrepancies. Finally, in the third phase, a saturation stage was conducted in which codes were grouped into thematic dimensions until additional interviews no longer yielded substantively new information. In addition, the frequency of use of each adaptation practice reported by respondents was recorded, and the origin of each practice was analyzed to determine whether it was autonomous, state-planned, or a combination of both. This process was complemented by the triangulation of field notes and photographic records, which strengthened the validity and reliability of the findings and provided a more comprehensive understanding of adaptive practices in the region.

TABLE 1 Domains for the classification of adaptation practices based on Schlingmann et al. (2021).

Domain	Description
1. Productive techniques	Methods and practices applied in subsistence activities, such as changes in farming or fishing techniques.
2. Inputs and productive resources	Provision of productive resources necessary for subsistence activities, including water, fertilizers, seeds, etc.
3. Subsistence products	Types of products generated or collected, such as crops, livestock, or fish. Changes in this domain may involve diversification or substitution of species.
4. Social and human capacity development	Improvements in community skills, knowledge, and organizational capacities, as well as in social cohesion and support networks.
5. Practiced livelihoods	Main subsistence activities practiced in the community, such as agriculture, livestock raising, fishing, or wage labor. Changes in this domain may include the adoption of new activities or the abandonment of others.
6. Location	Changes in the location of subsistence activities, including the displacement of crops, grazing, or fishing zones to new areas. Includes migratory processes.
7. Time management	Adjustments in the timing of activities, such as changes in agricultural calendars, fishing seasons, or working hours.

Source: Own elaboration.

The content analysis of the focus group was conducted by categorizing the transcriptions according to the core variables that comprise the IUPA (Aldunce et al., 2008). This qualitative approach enabled a deeper understanding of the perceived usefulness of the adaptation practices reported by small-scale farmers, prioritizing an interpretative comprehension rather than a quantitative measurement. Following the systematization and analysis of the interviews and focus group, we developed a set of recommendations aimed at formulating local adaptation strategies to climate variability, with an emphasis on strengthening the adaptive capacity of small-scale farming.

3 Results

3.1 Sociodemographic profile of small-scale farmers and the impact of droughts on productive systems

Of the 20 small-scale farmers interviewed to identify adaptation practices to droughts, 14 were women and 6 were men. Ninety percent reported being born in the archipelago, and 30% self-identified as Indigenous. Participants' ages ranged from 40 to 74 years (Mean ± SD = 59 ± 10). 65% receive support from state agricultural extension programs, and 85% reported not having completed secondary education. All families manage complex productive systems that integrate homegardens, livestock raising, potato fields, patches of native forest, fruit trees, and collected marine products.

3.2 Classification of adaptation practices by domain, frequency, and origin

To adapt to droughts, farmers reported 30 practices. These were classified based on domain, origin, and frequency. A total of 66% of the practices were autonomously implemented by farmers, 27% had a mixed origin, and only 7% corresponded to State-planned (Figure 3).

Techniques constitute a domain that grouped 35% of the identified practices. The majority of these are related to adjustments in the farm's water system as well as its vegetative cover. Rainwater harvesting (Figure 4) was reported by 100% of the interviewees, playing a fundamental role in adaptation to droughts. It is important to note that there are diverse harvesting systems, ranging from mechanized methods to others that rely on improvisation and reuse of materials:

> *"To have water in the summer, you have to collect it from any little source. And you have to build some half-roofs in the fields where there is no water and buy gutters and tanks… that is to capture rainwater and store it for the animals and the garden"* (Man, 61 years old).

On the other hand, 36% of the implemented adaptation measures corresponded to modifications in the management of inputs and resources for the maintenance of farming systems. Among these, water distribution via water tank trucks during the summer months by the State (50%) stands out, primarily intended for human consumption, with any surplus used to sustain farming systems. Additionally, among the most frequently mentioned actions was the purchase and storage of green fodder for animals (70%), ensuring livestock feeding during drought periods:

> "*Recently, the climate has become very drying and the pastures are drying up... there is no grass for the animals, and we have to buy bales of green fodder to feed the animals, and of course, that is a significant expense, but it has to be done nonetheless*" (Woman, 58 years old).

Regarding the subsistence products domain, this grouped 10% of the identified practices. Our results show that the cultivated area and livestock raising have decreased by 45% and 25%, respectively. Likewise, 65% of the interviewees mentioned making changes in the cultivated species to drought-tolerant ones. It is important to highlight that some farmers are selecting plant varieties, especially native Chiloé potatoes (Figure 5), which exhibit greater resistance to droughts and diseases associated with rising temperatures:

> *"This is the Murta potato, it is pink, it is the potato I love… It is very resistant to late blight and drought… and this is the blue potato, which I like a lot because it is firmer than the white and red potatoes. The one that has dried out a lot is the Roman potato, because it does not flower, so its growing process is shorter"* (woman, 40 years old).

Adaptations related to the capacity development domain accounted for 10%, highlighting the importance of maintaining good relationships with neighbors (50%). For example, in situations of water scarcity, some individuals share resources to assist those most affected:

> *"In our case here, we do have water, and if someone asks us for water, we give it to them... sharing water, I have always said that, if someone lacks water, they can come and get it" (Woman, 56 years old).*

Regarding the domain of practiced livelihoods, this represented only 3% of the total identified practices, concentrated in a single practice mentioned by 60% of participants, which relates to diversifying sources of family income. In this regard, salaried temporary or permanent employment of at least one family member has been increasing:

> *"This year I was invited to work in the blueberry fields; it is very good because it provides employment for many people. I even took my son to work there… It is an external income to the farm that also helps because you can earn more than one hundred thousand pesos [∼100 USD] a week… What do I do with that? I save it to buy my organic fertilizer or the plastic sheeting for my greenhouse"* (woman, 40 years old).

Additionally, 6% of the practices were associated with the location domain. Of these, 30% of farmers mentioned "moving their animals," that is, relocating livestock to areas outside the farm where sufficient water and pasture are available. This ensures that the animals have what they need to feed and remain healthy during drought periods. On the other hand, 30% of participants reported practicing "pasture rotation" to maintain the quantity and quality of forage in their productive systems: *"Well, to have good pasture we rotate the animals between pastures… we rotate them, they eat it, and then we move them to another pasture"* (Woman, 54 years old).

Finally, 6% of the practices were related to the time management domain, being the most frequently used by the farmers. Changes in work schedules are implemented by 80% of the participants, aiming to avoid the hottest hours of the day to protect people's health. Similarly, another adjustment in work timing has been changes in planting dates (70%). This mainly involves modifying the planting calendar to sow crops at more favorable times of the year, adapting to climate variations: *"Due to the change in climate, what we do is to sow earlier. For example, if we used to sow in the first week of September, this year we would have to move it forward to August, around mid-August, or the first of August, depending on how the weather is"* (Woman, 61 years old).

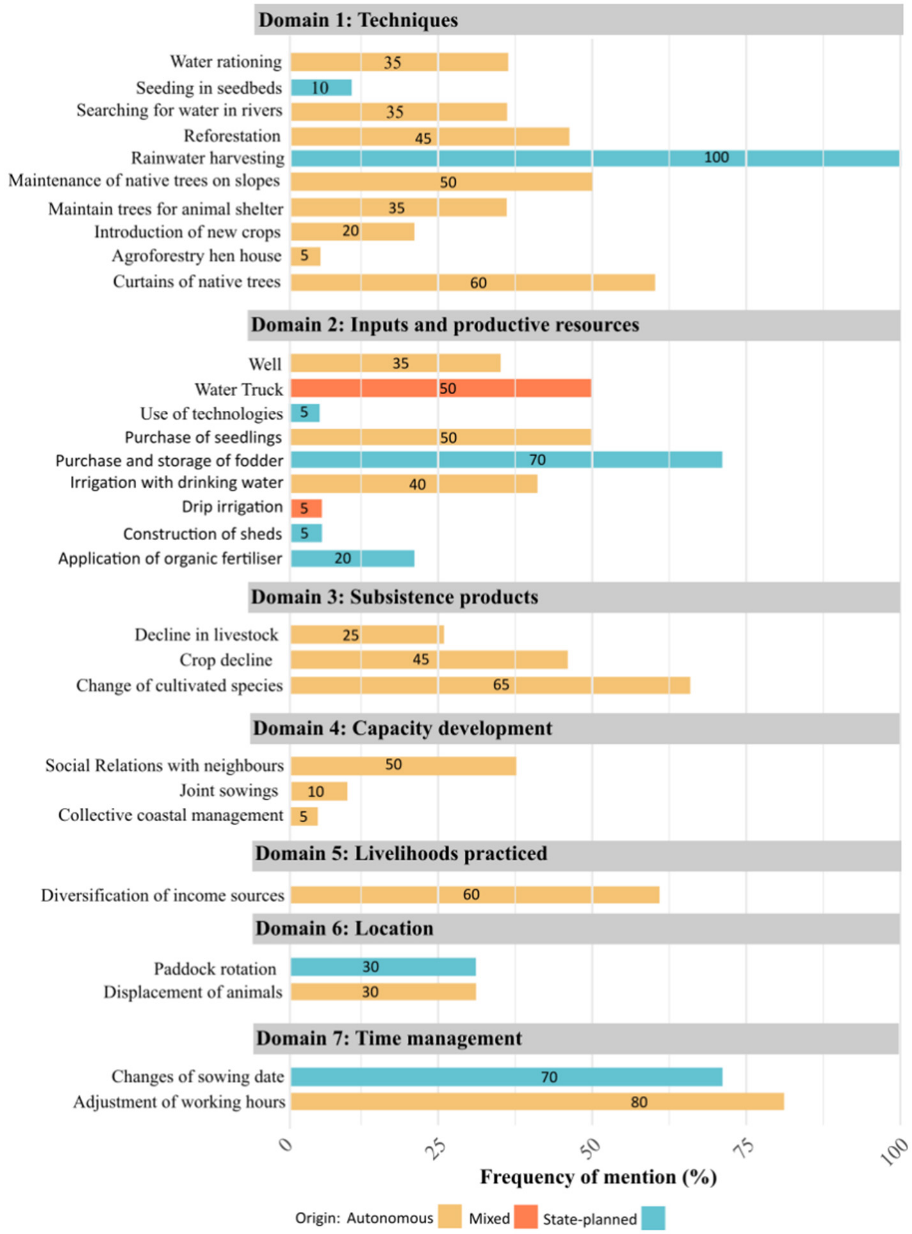

FIGURE 3
Adaptation practices to droughts implemented by small-scale farmers in Ancud, categorized by domain (seven categories), origin (three categories), and frequency of mention in interviews (100% = 20).

3.3 Community socialization and prioritization of adaptation practices to droughts

After participatory evaluation of adaptation practices during the focus group discussion, we collectively prioritized these adaptations into three categories (low, medium, and high effectiveness). Regarding the prioritization thresholds of the adaptation practices, eight were classified as low priority, ten as medium priority, and 12 as high priority. Among the adaptation practices categorized with low priority, notable ones include irrigation with APR, reduction of crops, animal relocation, collective management of the coastal edge, adjustment of work schedules, use of tanker trucks, livestock reduction, and water rationing.

These strategies implemented by small-scale farmers exhibit limitations in terms of effectiveness and long-term sustainability, highlighting the need to explore more robust and adaptive alternatives to face drought challenges. As mentioned in the focused discussion group, investing in more sustainable and permanent solutions, such as reforestation and the improvement of water systems, could provide more effective and lasting alternatives:

FIGURE 4
Examples of rainwater harvesting systems present in Ancud, Archipelago of Chiloé. On the left, an improvised system made with recycled materials; on the right, a mechanized system. Source: Photograph by the Authors.

FIGURE 5
Drought-resistant potato (*Solanum tuberosum*) varieties in the Ancud municipality, Archipelago of Chiloé. On the left, Murta potato; on the right, Blue potato. Source: Photograph by the Authors.

> *"There are some adaptation practices that one says, of course, there is no other alternative, but they are not ideal. For example, the issue of tanker trucks — we shouldn't need tanker trucks… people who needed tanker trucks before used to draw water from a stream or a spring. We need to solve that, not have water brought to me by a truck… so we shouldn't be telling the government to keep spending money on tanker trucks instead of seeking more permanent solutions, such as reforestation or creating community water systems"* (Focus Group).

Regarding the medium-priority practices, the purchase of tree seedlings, sourcing water from rivers, drip irrigation, maintaining good relationships with neighbors, the use of appropriate technologies, changing cultivated species, introducing new crops, purchasing forage, implementing agroforestry chicken coops, and water wells emerged. These strategies reflect a proactive and adaptive approach aimed at improving the adaptation of agricultural communities to local climate challenges. Nevertheless, participants discussed the monetary investment and benefits generated by some of these practices, considering more sustainable and cost-effective solutions to address water access during drought periods.

> *"It seems like a good idea to fetch water from the rivers, but you need a truck, fuel, and a motor pump to load it. I believe it makes more sense to promote rainwater harvesting systems"* (Focus Group).

Among the practices identified with high prioritization are rainwater harvesting, income diversification to mitigate economic risks, pasture rotation, seedling planting, and the maintenance of native trees in springs to ensure water regulation. Additionally, the maintenance of trees as shelter for animals and local biodiversity is promoted, along with the construction of barns to protect livestock and the planting of tree windbreaks to reduce erosion and provide favorable microclimates. Participants also emphasize collaboration among neighbors through joint planting to optimize resources and efforts. Likewise, adjusting the planting date according to changing climatic conditions was prioritized, together with the use of organic fertilizers to improve soil health and agricultural production.

> *"Look, what is happening is that suddenly there is a lot of rain, and then the sun comes out and hardens the soil. This harms the roots of whatever you have planted. For that, we have to use a lot of organic fertilizer. I like humus because it provides moisture content and makes the soil looser around the roots. [. . .] that organic soil gives more looseness to the plant's roots, because ordinary soil compacts"* (Focus Group).

3.4 Recommendations for local adaptation strategies to droughts

The following recommendations are derived from the community prioritization conducted with focus group participants. They aim to propose a framework for the formulation of inclusive and contextualized policies and strategies that not only recognize but also enhance local capacities to adapt to the changing conditions imposed by droughts. Based on our results, we propose the following recommendations to guide the design of public policies that strengthen adaptive capacity in small-scale farming systems: Strengthening productive diversification and income sources (R1), Reuse and efficient management of on-farm water (R2), Restoration of micro-watersheds (R3), Water governance with a community-based approach (R4), Scaling up agroecology (R5), and Land-use planning with a focus on the water system (R6). These recommendations are articulated across different scales of implementation—on-farm, community, and local or regional policy levels—as illustrated in Figure 6, recognizing that effective adaptation requires coordinated interventions at multiple levels of action.

3.4.1 Farm-level recommendations

Contemporary rurality, as expressed by its own protagonists, highlights the need for complementary income sources beyond the agricultural activities carried out on the farm. During the focus group discussion, it was emphasized that many farmers combine agricultural work with paid employment outside the agricultural sector. This diversification of production and income has become an increasingly common adaptation strategy, enabling the reduction of vulnerability associated with exclusive dependence on agriculture in the face of social-ecological changes.

> *"I work as a food service assistant at the school, I grow crops in a greenhouse, and I also do handicrafts. The complementary income allows me to continue farming"* (Focus Group).

The literature supports the effectiveness of diversification in reducing vulnerability to climate variability. For example, Antonelli et al. (2022) states that diversifying crops and non-agricultural income sources reduces the variability of well-being and the risk of losses in the face of extreme climate events, especially when both strategies are combined. Furthermore, their results show that a combination of high crop and income diversification yields the greatest impact in reducing the risk of losses associated with climate variability. Additionally, social capital is crucial for enhancing the effectiveness of diversification strategies (Caviedes et al., 2024, 2025).

Likewise, participants expressed the need to strengthen the restoration of micro-watersheds through community-based and/or self-managed water networks, in which local knowledge drives the collaborative management and use of water resources among neighbors and local governments. This need highlights the importance of coordinated actions at the farm-level (predial) that integrate adaptive management practices for soil and water.

In the context of small-scale farming, the improvement of rainwater harvesting systems and the modernization of irrigation were identified as crucial aspects. The results obtained highlight the urgency of developing strategies that address the diverse water demands, both for human consumption and productive uses. Among the proposals that emerged during the focus group discussion are the construction of water reservoirs (*tranques*), the establishment of shared deep wells among neighbors, and the implementation of greywater treatment wetlands, considered innovative solutions aimed at the reuse and efficient utilization of water resources at the farm-level (*predial*).

> *"Based on my experience, in the area where I live, I wish we could have a well shared by four neighbors, because the Rural Potable Water system (APR) does not allow us to draw water for the animals, and I manage around 20 animals, so it affects the availability of water for human consumption"* (Focus Group).

In line with the proposals made by the participants, Rofi and Saragih (2019) indicate that micro-watershed management through community participation improves access to water resources by establishing Water Management Committees. Among vulnerable groups, such as elderly women and children, their results show that the level of water consumption increased due to regulations governing the time and volume of water each family could collect, ensuring equitable distribution.

3.4.2 Community-level recommendations

Another factor affecting the water system is the reconfiguration of the rural space in Chiloé, a process driven by the sustained increase in land subdivisions at the local level, which in turn is overloading the APR networks. Unregulated land subdivisions are affecting water availability for residents across different sectors: *"The* land subdivisions *are using all the APR water because they*

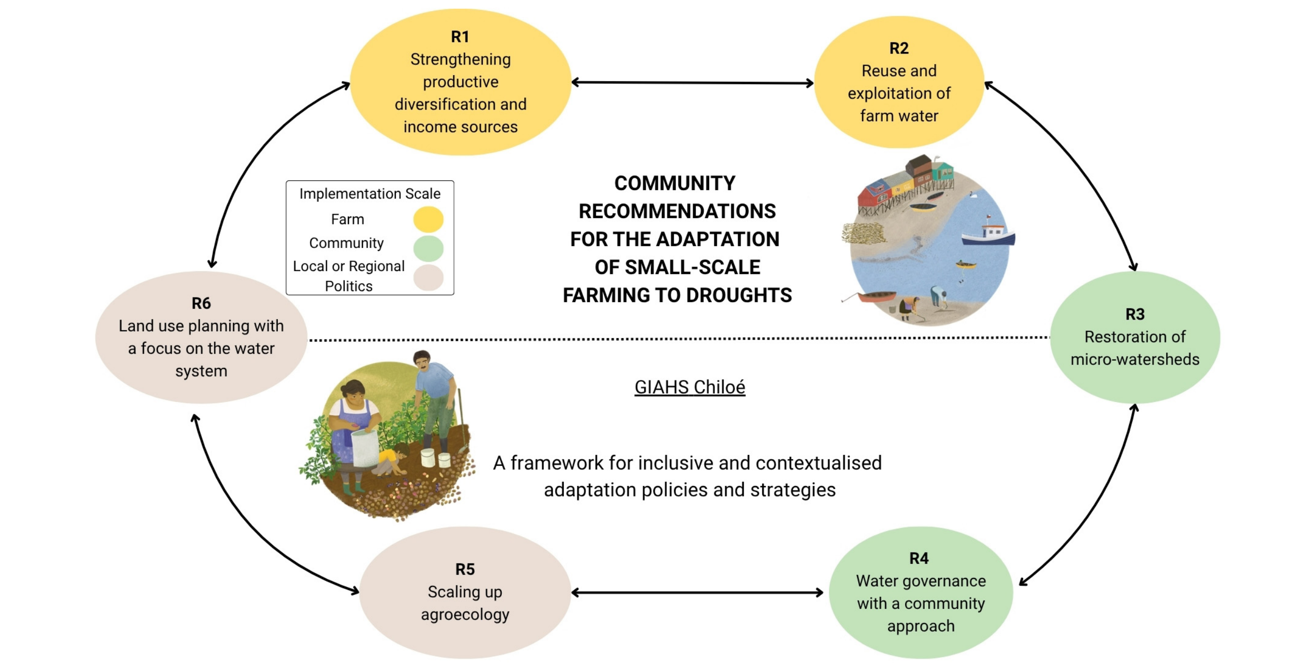

FIGURE 6
Recommendations for local drought adaptation strategies in a Globally Important Agricultural Heritage System (GIAHS) of southern Chile.

cannot find another solution. So, when the land subdivisions *are developed, they have to connect to our APR network, causing water shortages during the summer"* (Focus Group).

On the other hand, our results reinforce the importance of restoring the water system at the micro-watershed scale. Farmers argue that restoration begins with reforestation, both at the plot and landscape levels: *"There are springs that have vegetation, but no water. So, the vegetation on my plot is not the only important thing, because if there is a neighbor upstream who is cutting the vegetation, it affects the whole system"* (Focus Group).

In light of the social-ecological challenges faced by the Chiloé Archipelago, it is essential to promote community-based water governance. Achieving this requires strengthening organizational structures that foster collaboration and collective decision-making, ensuring that policies and strategies are inclusive and incorporate local knowledge: *"We are currently in an adaptation process in which we are responsible for generating governance, deciding how we, as farmers, influence political decisions"* (Focus Group).

In this regard, it is important to promote coordination and cohesion among the various stakeholders, including local governments, NGOs, universities, and local and Indigenous communities. A collaborative approach strengthens the adaptation of small-scale farming systems by fostering the exchange of knowledge and experiences, facilitating innovation, and enabling the incorporation of adaptive practices.

This recommendation is aligned with the findings of the recent Report to the United Nations on Water Security in Chile (Alvarez-Garreton et al., 2023). Within this framework, it is proposed to strengthen and incorporate territorial demands in the implementation of the Strategic Water Resource Plans in Watersheds (PERHC, its acronym in Spanish), promoted by the recently enacted Framework Law on Climate Change. This instrument includes three fundamental stages: watershed characterization, prioritization of actions, and the development of a management plan. Its implementation represents a key opportunity to integrate local governance approaches and ecosystem restoration, particularly in rural areas where access to water largely depends on community-based organizations or direct household management, both of which face multiple challenges in securing this resource.

3.4.3 Policy levers for systemic change

Another recommendation highlights the need to promote the scaling-up of agroecology in the territory. A key element is the production of organic fertilizers through traditional and livestock-based management, revitalizing forgotten practices:

> *"I have resumed enclosing my sheep... in the past, everyone used to enclose their animals, and with the manure produced in the sheds, they would all sow their crops. These practices have been abandoned, but we must recover them... not using any kind of chemicals, with agroecological management. We are in a GIAHS territory, which is of heritage value and must be preserved — not only for us, but for the future"* (Focus Group).

Among the actions that could strengthen this recommendation is the importance of having a local seed bank that is resilient to climate change and promoting seed exchanges among farmers. Seed saving and exchange should not be segregated, restricted, or controlled. On the contrary, it must remain free and be respected as a traditional practice essential to agrobiodiversity, food security, and food sovereignty. Additionally, the importance of incorporating biocultural memory into adaptation processes was emphasized, as it represents a body of inherited knowledge that is crucial for managing productive activities and life in general. Thus, agroecology is proposed by farmers as a fundamental guideline, since it has been proven to increase productivity levels even under adverse conditions. In summary, agroecology not only stands as an adaptive response to drought and social-ecological challenges but also revitalizes local practices and strengthens the autonomy of small-scale farmers.

This recommendation could be implemented by considering the five cross-sectoral measures proposed by RIMISP and PUC (2022) to carry out this process with the aim of strengthening food sovereignty in the Chiloé Archipelago. These include: (i) training of extension agents, decision-makers, and producers in agroecological principles and practices, articulation among agroecology trainers, and the enhancement of existing experimentation spaces; (ii) ensuring financial sustainability to support the integration and expansion of agroecology; (iii) promoting territorial relevance and a gender-sensitive approach; and (iv) consolidating agroecology as a long-term development horizon.

On the other hand, the hydrological system of the archipelago is highly dependent on native vegetation capable of retaining water, especially native forests and Sphagnum moss peatlands (*Sphagnum magellanicum*). In this regard, the need for effective land-use planning that protects and conserves the fragile island water system is emphasized:

> *"Our soil is the sponge that retains water, because this territory, being an island, is very fragile. Also, the rainfall regime has changed... It rains very heavily, it hits hard, erodes the soil, and the water runs off into the sea. If we have trees, we have Sphagnum, we have vegetation, the water will be absorbed and remain in the soil… We need to move forward with the reforestation of native vegetation and the protection of Sphagnum moss"* (Focus Group).

4 Discussion

This study contributes to global efforts aimed at strengthening the adaptive capacity of small-scale farming in the context of the ongoing social–ecological crisis. Specifically, we address drought as a key stressor, given the growing body of evidence on its detrimental effects on small-scale farming systems worldwide (Demem, 2023; Fernández et al., 2023; Camacho and Navarro, 2023; Tofu et al., 2023). Our results identify 30 drought adaptation practices within a Globally Important Agricultural Heritage System (GIAHS) in southern South America, a territory particularly sensitive to droughts due to its insular character (Iese et al., 2021a,b). Most of the reported practices (66%) were autonomous and rooted in local knowledge, followed by practices of mixed origin (27%) and a smaller proportion of State-promoted practices (7%).

The literature has documented the effects of drought on various small-scale farming systems. In Ethiopia, droughts have caused drastic reductions in livestock in the Dire and Yabelo regions (Demem, 2023). In the case of Colombia, a decline in pasture production and livestock farming was observed, which negatively affected the household incomes of small-scale farmers (Beltrán-Tolosa et al., 2022). On the other hand, in insular farming systems such as the Philippines, drought has led to reduced crop yields, economic hardship, migration, and transformations in livelihoods (Albarillo et al., 2020). Our findings support that, in southern Chile—as in other insular systems around the world—drought has emerged as a critical factor threatening the livelihoods of small-scale farmers in the Chiloé Archipelago.

Additionally, the results indicate that the adaptation practices developed in this small-scale farming system align with those reported in other global studies. In these, small-scale farmers have demonstrated diverse responses to changes in their territories, particularly regarding their production techniques (Camacho and Navarro, 2023; Daghagh Yazd et al., 2020; Piñeiro-Corbeira et al., 2022; Schlingmann et al., 2021). This study supports the need to consider integrated short- and long-term strategies at different levels, as exemplified by the Inuvialuit people in the Western Canadian Arctic in response to ice melt (Berkes and Jolly, 2002). For instance, immediate responses such as adjusting planting dates or improving on-farm infrastructure, combined with cultural and ecological adaptations related to reforestation, play a fundamental role in navigating the uncertainties posed by droughts. However, maladaptive practices exist that do not necessarily guarantee food security (Carmona, 2022). In fact, livestock reduction and a decrease in cultivated areas can harm food availability (Bahta and Myeki, 2022).

Small-scale farmers have made decisions such as seeking temporary employment outside their households to cope with the adverse effects of droughts, thereby diversifying and adjusting their practiced livelihoods. This diversification strategy is not unique to Chiloé; studies in other regions have demonstrated that income diversification can reduce vulnerability levels to climate variability and extreme events (Beltrán-Tolosa et al., 2022; Di Falco et al., 2011; Madhuri and Bhowmick, 2015). For instance, in the Zhagana Agriculture GIAHS, China, off-farm employment provides additional income to small-scale farmers, reducing their dependence on climate-sensitive sectors (agriculture and livestock), and supporting investments in adaptation practices to changes (Yang et al., 2018). However, the time devoted to external employment may limit the implementation of community adaptation practices and initiatives addressing droughts. Previous studies in Chiloé highlight that, while this diversification can improve families' financial capital, it can also impact social capital through the erosion of biocultural heritage and natural capital via ecosystem degradation (Oyarzo et al., 2024a).

Our study confirmed the importance of livelihood diversification among small-scale farmers in relation to the resources and adaptation capacities that each household can deploy to reduce their social-ecological vulnerability (Asfaw et al., 2021; Madhuri and Bhowmick, 2015). For example, actions dependent on farmers' social capital, such as joint planting and maintaining good neighborly relations, have been key to coping with droughts. These community practices not only strengthen social cohesion but also enhance farmers' capacity to share knowledge and resources, thereby facilitating the implementation of more effective adaptation strategies. On the other hand, while scientific knowledge, access to new technologies, and linkages with research centers and local governments contribute to the adaptation capacity of small-scale farming, local knowledge and practices are essential for adaptation processes and should be explicitly integrated and recognized in public policies (Jellason et al., 2022; Caviedes et al., 2023). In this regard, participatory evaluation of practices and co-construction of adaptation strategies are fundamental (Marchant et al., 2021).

According to the community evaluation and prioritization of adaptation practices, small-scale farmers highlighted that those related to reforestation are considered highly useful. This aligns with the argument presented by McCabe (2003), who states that reforestation is a crucial strategy for small-scale farmers to adapt to climate change and promote sustainable land-use practices. In this regard, the presence of native forest on farms is fundamental to the adaptive capacity of small-scale farmers, as forest cover provides shade and protection for livestock (Beltrán-Tolosa et al., 2022). Furthermore, the reforestation process contributes to biodiversity restoration and the maintenance of ecological balance within key ecosystems regulating the hydrological cycle (Ahmed and Stockle, 2016).

Similarly, agroecological management practices emerge as a guideline to produce food sustainably, protect the health of the social-ecological system, and avoid dependence on conventional techniques based on chemical products (Altieri, 1999; Cortés et al., 2023; Nicholls et al., 2015; Wezel et al., 2015). Historically, rural extension models in Chile have promoted the use of conventional technological packages at the expense of traditional practices (Marchant et al., 2020). Our results support that local small-scale farmers are oriented toward strengthening traditional knowledge for drought adaptation, and agroecology can play a leading role in this. The scaling up of agroecology should include both small-scale farmers and state rural extension programs. Rural dialogues coordinated by RIMISP, PUC, INDAP, and farmers from Chiloé propose Agroecological Schools as a strategy to strengthen technical capacities and promote these practices in small-scale farming (RIMISP and PUC, 2022).

Moreover, the agroecological lighthouse methodology has proven effective in disseminating agroecology; for instance, in Japan, it has amplified the adoption of principles and practices through the learning and reproduction of agroecological knowledge (McGreevy et al., 2021; Val et al., 2019). Likewise, in the department of Cundinamarca, Colombia, a network of agroecological lighthouses has been established, highlighting the coordinating potential of different local actors within this initiative (Vivas García et al., 2022). Similarly, in the Araucanía Region of Chile, institutional efforts have emerged to reorient the conventional extensionist approach through the Agroecological Sustainability and Transition Plan (2023–2026). This initiative outlines a roadmap to promote the transition toward sustainable agroecological production systems, where, for example, a network of 88 lighthouses has already been established.

In the current context of droughts, our results underscore the need to promote water governance that recognizes and values local capacities for self-organization, cooperation, and coordination with local governments. Therefore, rather than imposing external solutions, it is crucial to foster a polycentric approach that enables local communities to take an active role in managing their water resources, thereby ensuring sustainable and equitable water use in the region (Ostrom, 2014). Strengthening governance is a cross-cutting element permeating all the strategies proposed in this research.

The findings of this study are consistent with those presented by Nicolas-Artero and Blanco-Wells (2025), who evidenced the increasing dependence on water supply via tanker trucks in various rural areas of Chile, a process normalized by both communities and institutional actors. The Chilean State has chosen to address the summer water crisis by increasing investment in these sociotechnical devices, a decision questioned by farmers (Fernández et al., 2023). For example, between 2010 and 2019, 275 million US dollars (USD) were disbursed for water distribution in rural areas (Fernández et al., 2023). To counteract this short-term measure, local actors have promoted comprehensive initiatives capable of addressing droughts through integrated micro-basin management, incorporating both scientific and local knowledge for their governance (Frêne et al., 2022). Finally, it has been demonstrated that for drought response measures to succeed, they must be part of coordinated strategies under a community adaptation framework and not developed in isolation (Marchant et al., 2021). Thus, it is important to note that implementing these measures requires resource allocation at the local level, with an emphasis on anticipatory and bottom-up adaptation strategies.

5 Conclusion

Undoubtedly, small-scale farming systems face significant challenges, such as adapting to droughts, which constitute one of the main effects of current climate variability. In this regard, our study represents an effort to understand how small-scale farmers in a GIAHS in southern Chile are adapting to drought events within an archipelagic context.

In the face of the current social-ecological crisis, in which droughts increasingly impact small-scale farming systems with greater frequency and intensity, our research found that farmers develop adaptation practices of varying nature, encompassing both short-term adjustments in productive systems and long-term changes in the territories they inhabit. In this regard, the inclusion of participatory methodologies in research processes is vital to enhance adaptation and management efforts of GIAHS by involving local communities in the process, valuing their knowledge and experiences to create more effective strategies (Kaulen-Luks et al., 2022; Ibarra et al., 2023). On the other hand, Using the IUPA framework qualitatively allowed us to retain the multidimensional logic of the index while avoiding the reduction of complex local knowledge to numerical scores. This approach facilitated structured deliberation and comparative reflection across adaptation practices, supporting participatory prioritization rather than descriptive listing. However, the qualitative use of IUPA also entails limitations, particularly in terms of replicability and cross-case comparability. Despite these constraints, we argue that this approach is appropriate for exploratory and context-sensitive analyses in GIAHS settings, where the analytical emphasis lies on interpretation, relevance, and policy-oriented synthesis rather than index construction. The collaborative approach not only accelerates the delivery of useful outputs for adaptive capacity-building activities but also fosters trust in science and research processes within the community.

Additionally, the experiences of small-scale farmers constitute a fundamental asset to strengthen their adaptive capacity in the face of climate change. In this context, it is crucial to integrate local and Indigenous knowledge—often undervalued in public policy formulation—into processes of knowledge co-production, interinstitutional collaboration, and community empowerment for the adaptation of GIAHS. Furthermore, such efforts must be strongly aligned with the instruments established in Chile's Framework Law on Climate Change, including communal and sectoral adaptation plans, which provide concrete opportunities to strengthen local and territorial governance of climate change.

Finally, the recent announcement of the GIAHS Network in Chile, an emerging institutional framework aimed at coordinating public, private, and civil society actors around the protection, management, and valorization of traditional farming systems at the national level, represents a significant opportunity to advance these processes. In this regard, our findings open an opportunity to explore these adaptation processes in other recently recognized GIAHS sites in Chile; (1) Integrated system of camelid livestock and agriculture in northern Chile's High-Andean and Pre-Andean regions, and (2) Ancestral system of the Pehuenche Mountain Range: homegardens, gathering, and transhumance in the Ngulumapu territory.

In this context, its future consolidation could play a strategic role in formulating public policy recommendations based on participatory processes, strengthening community resource management, and promoting the adoption of adaptation practices that are culturally relevant as well as technically and socially feasible.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Comité de Ética-Bioética, Subcomité de Bioética "Investigación en Humanos", Universidad Austral de Chile. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

SK: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Validation, Writing – original draft, Writing – review & editing. CO: Conceptualization, Investigation, Methodology, Writing – original draft, Writing – review & editing. CM: Conceptualization, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Writing – review & editing. PR-D: Conceptualization, Investigation, Methodology, Supervision, Writing – review & editing. JC: Writing – review & editing. GS: Writing – original draft. JI: Supervision, Writing – review & editing.

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Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

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