frontiers | Frontiers in Water

TYPE Community Case Study
PUBLISHED 02 March 2026
DOI 10.3389/frwa.2026.1732846

OPEN ACCESS

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RECEIVED 26 October 2025
REVISED 31 December 2025
ACCEPTED 13 January 2026
PUBLISHED 02 March 2026

CITATION
Osorio A, Mazuera M, Baez Perez FA and Cristancho Garrido H (2026) Community water supply service systems in the high basin of the Guarino River (Marulanda, Caldas, Colombia) as territorialities for sustainability. *Front. Water* 8:1732846.
doi: 10.3389/frwa.2026.1732846

Community water supply service systems in the high basin of the Guarino River (Marulanda, Caldas, Colombia) as territorialities for sustainability

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Local community participation plays an increasingly important role in the sustainable management of river basins. Communities' contribution to protecting hydrological basins and the ecosystems surrounding them has been recognized in the political and scientific debate. Hence, protecting these ecosystems from a socio-ecosystemic approach is necessary. This research work, based on empirical evidence, aims to contribute to comprehending the relationship between communitarian action and the protection of river basins and the ecosystems surrounding them. For this purpose, we conduct a documentary and ethnographic study of the Community Water Supply Service Systems (CWS) located in the high and middle basin of the Guarino River in Marulanda, Caldas, Colombia. This work considers the communitarian character of these systems as well as their compatibility with the environment and their long-term sustainability. Recognizing some of these community systems as strategies for environmental protection and an efficient supply of water services is necessary for improving water management in river basins. It also recognizes the indissociable relationship existing between environmental sustainability and the construction of territorialities around community governance of water resources in rural areas.

KEYWORDS

community participation, governance, river basin, sustainable management, territoriality, Colombia

Introduction

Biodiversity loss and ecosystem degradation require land use planning and environmental protection from a hydrological basin approach, focusing on sustainable natural resource management (Craven et al., 2017; Kennedy et al., 2019). Basins concentrate water from precipitation, creating interdependence between water users at the river basin level (Dourojeanni et al., 2002; Braz et al., 2020). Although internationally promoted, implementing this approach on the administrative and financial levels has been challenging (Vieillard-Coffre, 2001; Ghiotti, 2006).

In Colombia, river basin planning dates back to the 1950s, with the first management plans for the Cauca River basin (Buitrago-Bermúdez, 2014). Regulations have since evolved, with the hydrological basin regime governed by decree-law 2811/1974, law 99/1993, and the National Integrated Water Resources Management Policy. Due to social issues like violence, corruption, and weak state institutions, the challenges to implementing the regulations persist (Buitrago-Bermúdez, 2014; Castro-Buitrago et al., 2018). The policy stresses the importance of efficient water management, including sewage and saving strategies, which influence water flow quality and quantity (Dourojeanni et al., 2002). However, service execution remains inadequate. Around 15% of Colombia's population lacks water services, and 33% of municipalities lack proper wastewater disposal systems (Alfonso and Castro, 2022). In addition, service fares have increased significantly, leading to reduced consumption and service discontinuation due to non-payment, especially in low-income communities. Moreover, water quality is often poor, and supply interruptions are common (Alfonso and Castro, 2022).

Further challenges include significant gaps in water service data, as many suppliers provide limited information or operate irregularly without legal status or water permits (Prieto Acero and Murcia Hernandez, 2011; Quintero-Culma and Romero-Bustos, 2020). These irregularities hinder adequate service monitoring, which, according to Colombian law, is formally the responsibility of the state in the case of water supply and sanitation services. Law 142 of 1994 allows third-party participation in the provision of these services, largely as a result of privatization processes and the state's structural inability to ensure nationwide coverage (Montoya-Domínguez and Rojas-Robles, 2019). This regulatory framework raises concerns regarding the human right to water, as service provision is frequently conditional on users' ability to pay, disproportionately affecting low-income and rural populations (Bernal, 2022).

In this Colombian context, community-managed water supply systems (CWS) provide approximately 40% of rural water supply, involving more than 12,000 local providers nationwide (Moncada-Mesa et al., 2013; Ecuyer, 2022). However, the mere existence of CWS should not always be interpreted as a voluntary model of service provision, but rather as a collective strategy to respond to structural inequality in access to essential services such as water. Indeed, in most cases, community management is a territorial and political response to injustices in access to domestic water services, mainly in rural areas. From the perspective of Latin American political ecology, approaches based on communality and community interconnections are proposed as alternatives to the crisis of civilization and neoliberal domination. These proposals seek a more equitable and sustainable relationship with common goods, including water (Roca-Servat et al., 2021). Specifically regarding access to and exclusion from water services, Swyngedouw (2004) demonstrates, in the case of Guayaquil, that these dynamics are not conditioned by the physical availability of water in the territories, but rather by the socioeconomic and political-geographic power relations that structure them.

Despite their role in supplying water services in Colombia, the CWS still face challenges related to their lack of formal recognition and registration. An official response from the Governor's Office of Caldas highlighted that the irregular legal status of CWS significantly limits the state's ability to track service provision and ensure regulatory oversight. This situation underscores the need for systematic assessment of CWS in order to improve understanding of community-based water governance and its implications for ecosystem protection at the river basin scale.

By using the term 'CWS', this paper seeks to acknowledge the heterogeneity of these community-based water providers, which in some cases deliver treated water and in others supply untreated water. In both scenarios, however, CWS are deeply embedded in local identities, territorial practices, and traditional ecological knowledge, playing a crucial yet insufficiently recognized role within Colombia's formal water governance structures (Bernal-Pedraza, 2021).

Faced with increasing demand for water for multiple, often conflicting uses (human consumption, agriculture, livestock, rural tourism, etc.), CWS are finding it difficult to operate, among other things, they must comply with regulations designed for large companies. CWS in Colombia have proven to be a supportive and cooperative response to the lack of infrastructure, but they face regulatory barriers and external pressures that complicate their sustainability (Murcia-Castillo and Francel-Delgado, 2022).

Following Sack's original approach (Sack, 1986), territoriality is a social construction that depends on who controls whom and for what purpose. In the case of CWS, generally managed by farmers in rural areas, territoriality oriented toward sustainability refers to the social arrangements that enable the collective care of water, both for its preservation as a natural resource and for human use, while taking environmental and social needs into account. In this sense, territorialities for sustainability align with, or closely resemble, what are known as "hydrosocial territories," understood as "spatial configurations of people, institutions, water flows, hydraulic technology, and the biophysical environment that revolve around the control of water" (Boelens et al., 2016).

This article focuses on analyzing four CWS in the Guarino River basin in central Colombia, a region that provides key ecosystemic services like water supply for over 115,000 residents of Caldas and Tolima (Tobón, 2013). Despite this, official records on water and sewage systems are limited. Previous studies (Quintero-Jiménez, 2022) highlight alarming issues related to ecosystem health and water quality, as well as other challenges CWS face. Threats include pollution, erosion, deforestation, and untreated wastewater entering river basins.

Academic interest in the Guarino River basin has increased over the past decade, with research focusing mainly on social and environmental issues. Fewer studies have explored the basin's physiological aspects. Notable contributions include Walteros Rodríguez and Daza Castro (2008), who used bioindicators to assess water quality, and Benjumea-Hoyos et al. (2014), who analyzed water transfer. Grajales-Noreña and Naranjo Cárdenas (2021) assessed environmental risks linked to the hydroelectric project in Marulanda's Montebonito district. Portuguez (2015) estimated direct runoff using GIS, while Ríos-Pulgarín et al. (2016a, 2016b) studied the hydrological cycle's role in fish distribution. On social and environmental topics, studies on citizen participation and conflicts related to hydroelectric projects stand out (Munévar-Quintero and Valencia-Hernández, 2015; Munévar-Quintero, 2011; Cifuentes-Osorio et al., 2021). However, few studies address water supply and none have studied the water supply systems in this basin in a comprehensive manner. Moreover, most focus on the issue of drinking water treatment, such as Florez Guerrero (2022), who evaluated the hydraulic function of the El Llano treatment plant in La Dorada (Caldas). This represents a gap in literature, in particular for the case of Marulanda, for which no studies on water supply systems were found. This paper aims to contribute to filling this gap in literature on community water governance in this territory.

The article will present the research methodology, discuss the findings, and offer conclusions on integrated river basin planning for water management in Colombia.

Context

Territory of study

This study centers on the high basin of the Guarino River in Colombia's Caldas department, where the Marulanda municipality is located. Marulanda's political and administrative composition consists of 12 *veredas*[1] and one district (Figure 1). It extends along 37.857 hectares, 18.50% being urban area and 81.50% being rural area, according to Corpocaldas and Fundación para el Desarrollo Comunitario de Samaná (FUNDECOS).

Marulanda is home to the Guarino River headwater, which crosses the town from the northwest to the southeast, where it meets the Perrillo River and continues alongside the department limits with Tolima toward its mouth onto the great Magdalena River in La Dorada. With an approximate extension of 837.45 km2, the Guarino River basin crosses Caldas department, passing through Marulanda (44.84%), Manzanares (21.78%), Marquetalia (3.26%), Victoria (4.42%) and La Dorada (0.71%), and Tolima department through Herveo (9.47%), Fresno (9.50%), Mariquita (3.43%) and Honda (2.60%) (Duque-Escobar, 2011) (Figure 1).

Marulanda's economy relies heavily on its mountainous landscape, as seen in field visits and community interactions. There are two main areas in Marulanda, in demographic, administrative and economic terms, with limited communication between them. The cold weather in the first area, due to its proximity to the paramo ecosystem, supports an economy focused on cattle and sheep breeding on medium to large ranches and timber exploitation. This area is also the nearest to the town's center. The second area, Montebonito, located southeast along the Guarino River, presents warmer weather and an economy based on crops like plantain (for self-consumption) and coffee and avocado (for commercialization). Montebonito has a higher population with smaller agricultural plots and a focus on family farming.

Methods

This is qualitative research using the ethnographic method and documentary review as the main sources of information. Thus, the data collection techniques were based on: 1) documentary analysis of scientific works, official documents and documents provided by the CWSboards of directors; 2) direct observation based on various tours to identify the functioning of the CWS and; 3) the application of semi-structured interviews by means of intentional sampling and by convenience, as we sought to know the perspective of members of the boards of directors, CWS users, employees of public entities, among others.

To establish which CWS would be involved in the study, access to official information from Caldas Governor's Office was requested through the right of petition. This allowed us to identify two public water and sewage service suppliers, one of whom also provides sanitation services. The first supplier, EMPOCALDAS S.A.E.S.P., operates with private funding and provides CWS service to 395 users and sewage to 383. The second supplier, Montebonito Marulanda Public Services Association, provides CWS service to 282 users, and sewage and sanitation to 250. The latter is considered a CWS for this study.

Marulanda's Municipal Development Plan (2020–2023) was consulted as complementary information. We also conducted on-site visits to Marulanda's Mayor's Office and public services companies in the town's urban center. Three other informal suppliers considered CWS were identified afterwards. These suppliers are located in El Páramo, Naranjal, and Santa Clara *veredas* (Figure 2).

The four CWS studied come from historical processes of collective action within local communities to guarantee water supply both in rural and urban areas of Marulanda. Fifty-one interviews were conducted amongst beneficiaries, workers and board members of the working CWS in El Páramo, Naranjal, and Santa Clara *veredas*, and the urban centre of Montebonito district. Most interviews were conducted in Montebonito (22), followed by Santa Clara (15), Naranjal (10), and El Páramo (4). This information was built both via semi-structured interviews. In addition, coding was used as an analytical tool for the organization and treatment of the data derived from the interviews, using the NVivo software.

For the application of the interviews, a semi-structured guide was constructed with five thematic blocks: (1) knowledge of the CWS and life history linked to them, (2) Perception of the functioning of the CWS, (3) Participation in the CWS, (4) The CWS and the protection of the environment, and (5) Articulation of the CWS in networks of different scales. It is also relevant to mention that it was not necessary to adapt the questions for the different participating groups, since they were formulated with the objective of congruently covering the perceptions of the different roles associated with CWS. However, for the members of the boards of directors, CWS workers and public employees, emphasis was placed on their opinions on water quality, forms of participation in water management and the processes of consolidation of the CWS over time. For further information on the methodological process and to view the interview guides, see Annex 1.

In this work, we employed Elinor Ostrom's theory of the commons (1990) to structure the analysis of the conducted interviews, keeping in line with other research on CWS in Colombia (Delgado-Serrano et al., 2017; Soto-Vallejo et al., 2020; Osorio, 2021). The management of the commons expresses the possibility of developing a collective management of resources that can be environmentally sustainable in the long term. Ostrom (1990) points out eight principles:

1. Boundaries are clearly defined
2. Rules adapt to the local context
3. Decision-making processes are participatory
4. Monitoring is conducted
5. Graduating Sanctions
6. There are easily accessible conflict resolution strategies
7. Commons present a legal status, hence the right to organize
8. Commons are embedded within larger networks

Community water supply systems have become key scenarios for analyzing self-governance and sustainability capacity from Elinor Ostrom's theoretical framework. These systems manage to collectively manage a common resource by applying design principles that promote collective action, trust and cooperation. Participatory

1 *Vereda* refers to a Colombian administrative division with a smaller population than that of a municipality, predominantly in rural areas.

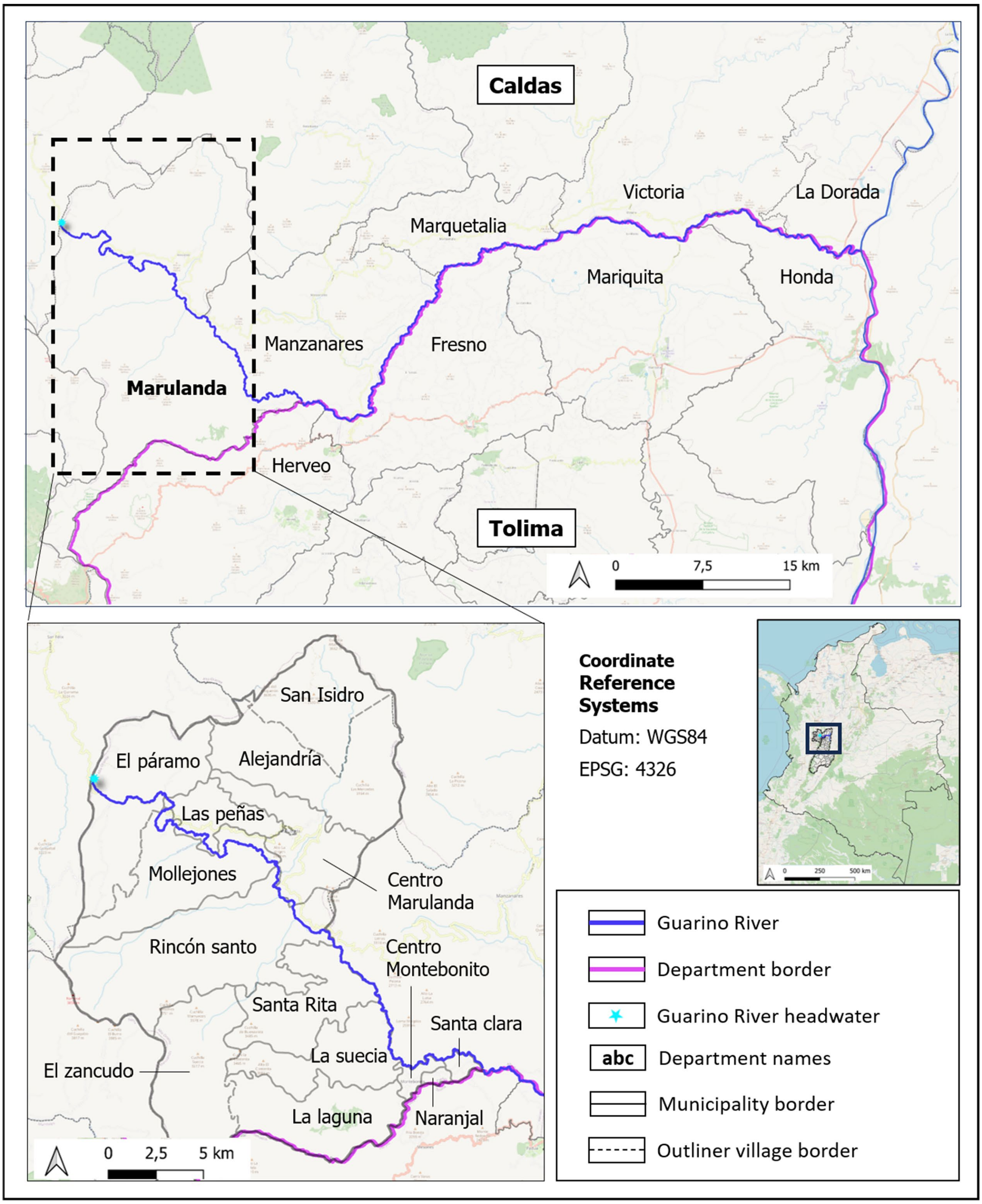

FIGURE 1
Administrative division of Marulanda, Caldas (Colombia).

decision-making, for example, has proven to be a key factor in strengthening social cohesion and a sense of belonging, as demonstrated by community organizations in Janiuay, Philippines (Salazar, 2025). Similarly, the establishment of collective choice agreements and mechanisms for oversight, sanctions, and conflict resolution has been crucial to ensuring long-term stability, as documented in Faisalabad, Pakistan (Altaf and Goetzke, 2025). These cases demonstrate that the sustainability of systems depends not only on formal structures but also on inclusive processes that enhance the legitimacy of community governance.

Another important aspect highlighted by Ostrom is the need for a balance between community self-management and external support. In Uganda, for example, the success of community water systems has been conditioned by the presence of organizational characteristics

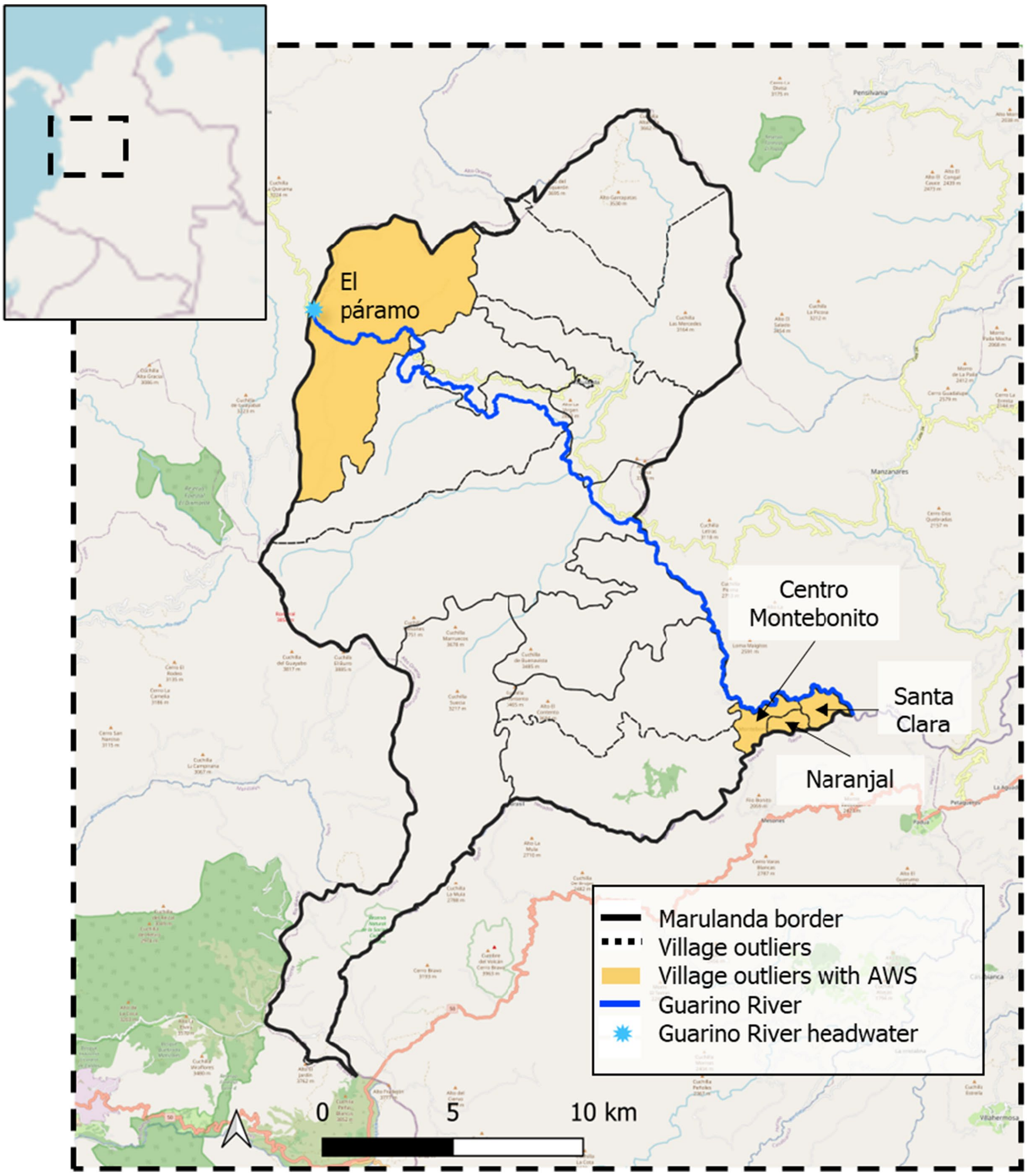

FIGURE 2
Community water supply service systems in Marulanda, Caldas (Colombia).

aligned with design principles (Naiga, 2018). Added to this is the role of social capital as a driver of effective management, as shared interests and community commitment have contributed to the construction of identity and cohesion, as observed in local experiences in Slovenia (Pipan et al., 2023). Finally, adaptive governance is a central element, as it allows formal and informal rules to be adjusted to changing contexts. This has been evident in irrigation communities in southern India, where the effectiveness of Ostrom's principles depends on specific biophysical and social attributes (Vallury et al., 2022). Taken together, these experiences confirm that community self-governance can be sustained over time when it articulates institutional structures, social capital, and adaptive mechanisms, although its success remains highly dependent on context (Saldaña Almazán et al., 2025; Tsuyuguchi et al., 2020).

In general, analyses of community-based water supply systems grounded in Ostrom's theoretical framework highlight the capacity of communities to self-organize, establish their own rules, and sustainably manage common-pool resources, thus avoiding the "tragedy of the commons." In Colombia, studies on these systems emphasize participatory governance, where local organizations take collective responsibility for resource management, strengthening democratic processes and challenging privatization models (Llano-Arias, 2015;

Perera, 2015). Some studies focus on polycentric governance contexts, in which multiple actors—community-based, state, and private—interact, fostering resilience and promoting sustainability (De Luque-Villa and González-Méndez, 2022). Others argue that community-based systems have become spaces for social mobilization and political participation, contributing to peacebuilding in regions historically affected by armed conflict (Llano-Arias, 2015; Perera, 2015). Educational strategies and collective action initiatives have also been implemented to strengthen cooperation, equitable distribution, and community cohesion (Bernal-Escobar et al., 2025). These systems are also at the forefront of advocacy for socio-environmental recognition and justice, promoting water as a common good and a human right (Blanco-Moreno and Peña-Varón, 2023), while applying principles of sustainable management that help mitigate tensions arising from scarcity. Despite these advances, previous findings indicate that organizational weaknesses and regulatory constraints persist, underscoring the need to strengthen local capacities and integrate these models into national and international water governance policies, thereby maximizing their potential in the sustainable management of common-pool resources (Furlong et al., 2018; Soto-Vallejo et al., 2020; De Luque-Villa and González-Méndez, 2022).

The results obtained using the methodology presented above are presented below. For details on the interviewees, refer to Annex 2.

Results

CWS conformation process

The consolidation of each CWS varies in terms of time frames, actors, and legal status. Only Montebonito CWS is legally recognized as a public service supply company with a water concession.

The CWS in El Páramo began its construction in 1967 as a project by the Community Action Board and the late *Instituto Nacional de los Recursos Naturales Renovables y del Ambiente* (INDERENA). Between 1999 and 2007, the number of beneficiaries decreased due to forced displacement derived from the armed conflict, as explained by a community leader and CWS manager:

> "Between 1999 and 2007 was the period with more forced displacement in the community due to the armed conflict we had here in the region. Then, fewer neighbors were left and, in the end, only three families remained. Now, we are settling in town again. We are currently around 90 people living here in the district again (El Páramo CWS user)."

Fifteen families benefited from the CWS in Montebonito before 1940. Afterward, members of the community would carry the water from the river's creeks or its headwaters to their homes. In this decade, the community organized itself informally. Then, in 1947, they began the aqueduct's technification with the assembly of storage tanks and the installation of asbestos pipelines (Figure 3).

- The CWS in Naranjal and Santa Clara had no structure that allowed direct water supply to people's homes until about ten years ago. Up until then, the community had put together a system of hosepipes from the river flow. Direct home supply was possible thanks to external institutional funding –the Coffee Producers Committee of El Naranjal and a foreign coffee producer company, according to users in Santa Clara.

Currently, CWS studied present differentiated management in terms of quantity of beneficiaries, pricing of water uses, governance, and participation. The variety of the management systems will be interpreted according to the design principles stated in Ostrom (1990) for the study of the governance and self-management of commons.

Boundaries are clearly defined

All four CWS studied have clearly defined areas of operation and records of the exact number of households supplied (Montebonito, 282 households; Santa Clara, 79; Naranjal, 50; El Páramo 13 households and one rural school). Thus, these CWS comply with the first principle.

Rules adapt to the local context

Pricing amongst the CWS varies widely. In Santa Clara, consumers do not pay for the services, thanks to the collective management and maintenance of the CWS, as declared by users themselves.

> "We are all in charge of overseeing possible damages and the correct flow of the water, or if it's necessary to wash the tanks, or maybe the levels are low, then we all pay attention (Santa Clara CWS user)."
>
> "When fixing is needed, for instance, people gather and do it. When you cannot, the others come and fix it (Santa Clara CWS user)."

Whereas CWS in El Páramo and Naranjal established a fixed monthly fee that allows paying someone who oversees the maintenance of the structure (tank and mouth) in El Páramo, and a plumber in Naranjal. Still, the community participates in maintenance activities when needed, as confirmed by a user of Naranjal CWS when responding to the question *'Have you participated in organization, building, or maintenance activities in the CWS?'*

> "Gatherings[2] have been made, when a winter wave comes in, there's a downfall, there's damage in the pipeline. A gathering is done to organize it or for other stuff we have gathered (Naranjal CWS user)."

Finally, Montebonito CWS has established a fee that varies according to the consumption rate per user, determined by individual water meters. The payment makes up for the salaries of employees (a plumber and a secretary). Note that this CWS also provides sewage and cleaning

2 In the Andean region of Colombia, the term *convite* is used to name the process where a rural community gathers to develop a communal work that can take one or more days and where each participant contributes with their work of labor, food or training (Pérez-Fonseca, 2018).

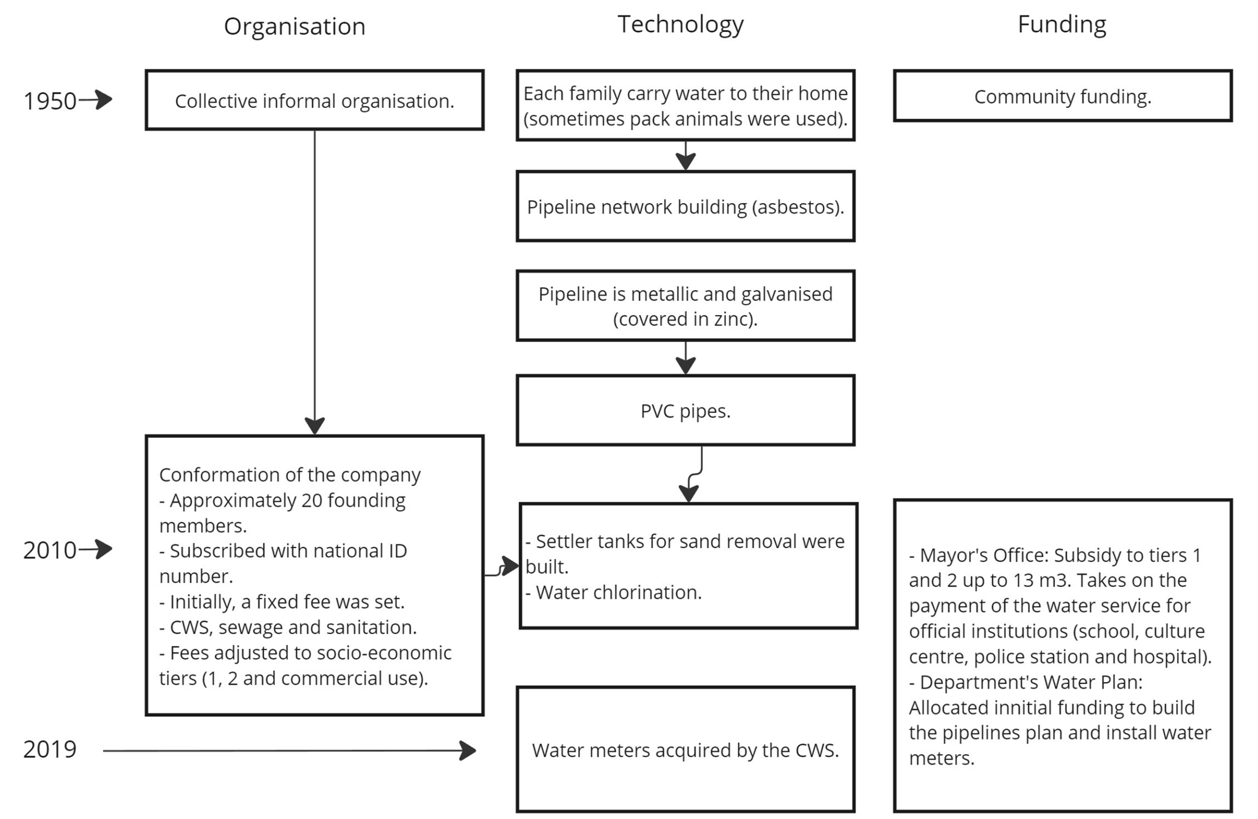

FIGURE 3
Montebonito CWS conformation.

services. Montebonito is classified in socio-economic tiers[3] 1 and 2, and the Mayor's Office subsidizes 70% of the total fee in tier 1 and 30% in tier 2, as long as the consumption does not exceed 13 m3 per household. In addition, the Mayor's Office is responsible for the payment of the services of official institutions such as the school, the police station, and the cultural centre. Meanwhile, commercial establishments pay an additional fee, which contributes to the subsidiary system.

Some households affiliated with the CWS studied collect rainwater. This practice is not promoted by the CWS but rather done autonomously when facing water cuts or damage to the structure. This study identified that rainwater collected is often used for cleaning.

> "User: [Rainwater is used] to wash the coffee, fumigate…
>
> Interviewer: To wash animals, too?
>
> User: No, for animals, not so much. But rather to wash the coffee and fumigate (Naranjal CWS user)."

Beneficiaries in El Páramo, Montebonito and Naranjal reported that they employ water supplied by the CWS not only for human consumption but also for purposes related to agriculture, such as washing coffee, fumigating[4] avocado cropping and washing barns and garages. This was confirmed by the management teams of the CWS and official data from Corpocaldas (Figure 4).

Principle number 2 is partially met, according to the results of the study. We found some gaps between the determined water uses and the local conditions. However, the communities have established functional systems that seem to respond to their specific conditions, like cash payments in some cases and collective work in others. Three out of four CWS studied do not have water purification systems, despite communities using the water provided for human consumption. Hence, this gap poses the need for access to drinking water on one end, and the technologies employed by the CWS on the other.

Decision-making processes are participatory

Only the CWS in Montebonito gathers on a clearly regular basis, twice a year and has periodic board meetings to elect the members that will assume the direction roles. The other three cases

3 According to the DANE, social tiers in Colombia are employed as a socioeconomic stratification to classify residential properties with access to public services. This stratification ranges from 1 to 6 as follows: (1) low-low, (2) low, (3) medium-low, (4) medium, (5) medium-high, and (6) high. It's used with the aim of pricing public services in a differential way so that users with higher incomes pay more and consequently, users with lower incomes pay lower prices and/or might receive subsidies.

4 Local term referring to crop fumigation processes, especially avocado crops.

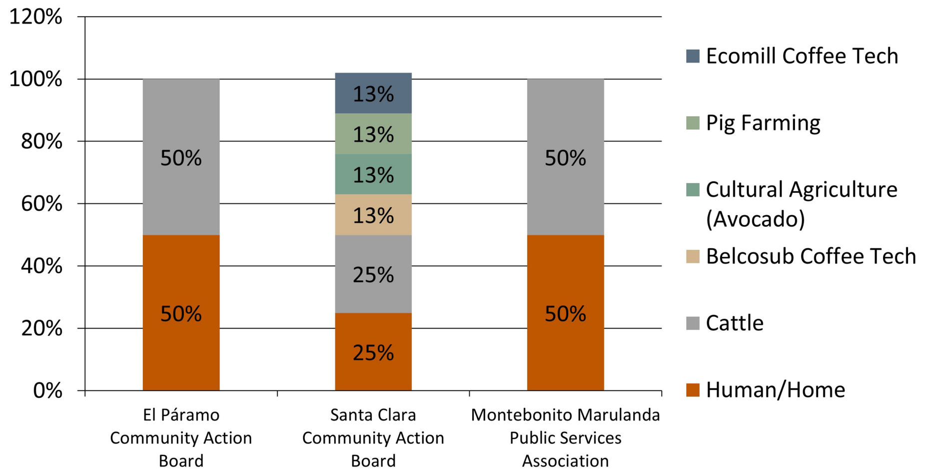

FIGURE 4
Distribution of water use in Marulanda CWS. Figure built with reference data from Corporación Autónoma Regional de Caldas and Universidad Tecnológica de Pereira (2016).

of study present different dynamics of dialogue and socialization involving the management of CWS. Naranjal, Santa Clara and El Páramo hold gatherings according to the needs when there is a specific situation affecting or altering the service. For instance, when the pipelines present damage or when fees are altered, as users say:

> "We [the directors' board] gather every 6 months, twice a year. Sometimes, when necessary, we have an extraordinary meeting, but it's rare since the CWS does not have any problem, no (Montebonito CWS user)."
>
> "Interviewer: Does the CWS have a set regular meeting? Every year or every 6 months, for instance?
>
> User: No, maybe when there's some damage or when they readjust the fees, then they gather the people, to tell them, but other than that, meetings, not really (Naranjal CWS user)."
>
> "When there's damage, reunions are called, but that's not usual (Santa Clara CWS user)."

Leaders of the CWS in El Páramo, Santa Clara, and Naranjal are selected based on their recognized roles as community leaders, yet the statutes do not establish formal rules for election, rotation, or renewal of roles and responsibilities. Leadership changes are generally limited to resignation or death, resulting in governance arrangements that rely heavily on informal legitimacy and personal commitment rather than institutionalized democratic procedures.

The empirical findings highlight the central role of women in both the day-to-day and political management of water, in line with other research on water management in Colombia (Torregroza-Espinosa et al., 2025). This is illustrated, for example, by the case of Montebonito, whose system is managed by a woman who replaced her mother, illustrating the intergenerational transmission of knowledge and responsibility in water management and governance.

Similarly, in the two sectors of Santa Clara, women lead water governance processes while facing persistent challenges in reconciling domestic and care tasks with management responsibilities, as illustrated by the following interview excerpt:

> "It has been very hard for me because I managed everything in the system, I had to go to many meetings and I was also in charge of the house. I am tired now, I feel exhausted. I cannot cope with so many things anymore. With the house, with everything. (CWS leader)."

In addition to the challenges faced by women leaders, the results of the fieldwork reveal other obstacles to broad community participation in community processes. These challenges faced by women leaders coincide with other research (Imburgia et al., 2020; Leigh Hamlet et al., 2022) showing that women leaders in community water management associations face significant challenges and bear a 'triple burden' of domestic, subsistence and governance tasks, which can impact their effective leadership role and reinforce unequal gender relations in political and community participation (Adams et al., 2018).

As well as the challenges faced by women leaders, the results of the fieldwork reveal other obstacles to broad community participation in community processes, as illustrated by the case of CWS Montebonito, where board members must pay a fee to access this decision-making space. This condition was stipulated by the company's statutes (2010) by agreement of the 19 original members, but without the participation of the rest of the beneficiaries. Some beneficiaries resist it since they would like to take part in the management and decision-making process of the CWS, but they aren't willing or capable of paying for a subscription to the board.

> "No one knew when they called to join the board (Montebonito CWS user)."
>
> "I would have liked to join the board, but I did not hear anything (Montebonito CWS user)."

The findings from the Montebonito CWS reveal important tensions between formal participatory arrangements and their actual operation in practice. While the existence of a direction board suggests compliance with collective-choice principles commonly associated with community-based governance (Ostrom, 1990), the requirement to pay a fixed fee in order to participate effectively limits access to decision-making to those with sufficient economic resources. This rule cannot be understood as a neutral administrative mechanism, but rather as a socio-economic filter that reproduces broader inequalities in access to authority and voice within the system (Swyngedouw, 2004). This dynamic also illustrates that decision-making on water-related issues and, more generally, the implementation of water governance can lead to unequal benefits or even the exclusion of certain stakeholders (Boelens et al., 2016) reproducing unequal power relations over time.

Based on the findings, the third principle is only partially met. Although formal collective decision-making arrangements exist, some users perceive that key management decisions are not made through inclusive processes, raising questions about the effectiveness of the current CWS governance system.

Monitoring is conducted

All four CWS undergo system monitoring, with responsibility held by either the community or a dedicated management team. For Naranjal, Santa Clara, and Montebonito CWS, this often involves a plumber, while El Páramo CWS has a management team conducting household tap condition checks. In contrast, the Caldas Territorial Direction of Health periodically samples water quality in Santa Clara, Naranjal, and Montebonito. Sampling evidence has shown that the water provided by these CWS is highly dangerous for human health or sanitarily inviable. According to Colombia's water quality risk index (IRCA), which grades water risk using 23 parameters, El Páramo and Naranjal CWS have IRCA scores of 97.8 and 97.6, respectively, classifying their water as healthwise unfeasible. Santa Clara CWS has a high-risk IRCA score of 79.4. Notably, Montebonito is the only CWS studied with no identified water quality risk.

Pollution in the water employed by the CWS seems to be related to the trespassing of the demarcated area prioritized for protecting the hydrological resources and the connected ecosystems. Trespassing is related to anthropogenic activities such as cattle ranching and monocrops. According to a user, these activities affect people's health:

> "I always tell the users: 'boil your water. Do not drink water directly from the tap. Because the truth is, the avocado crops in the upper side of the mouth are fumigated up there, and all that comes down here. They take me, they put me in here, and I need to wear two or three facemasks. I choke here with that venom they spread (…) I get deadly headaches. So much so that I had to go to the hospital once. I got sick (Santa Clara CWS user)."

The surrounding areas suffer high pressure derived from deforestation, which might be impacting the flow of the water, according to a user of Montebonito CWS:

> "Right now [the situation of the Guarino River] is really bad because past governments did not care to come here and build a prudent fence to reforest properly. They came here, they brought some sticks and gave them to students and contractors, and that was it –there's your live fence. We have an entrance to the river for the cattle, and we need help with that. We need reforestation, otherwise we will be left without water in 8 or 10 years." (User in Montebonito).

CWS not only provide water supply but also manages hydrological resources and protect water sources. They engage in forest restoration and the protection of critical ecosystems. However, pollution from agricultural activities threatens these efforts, leading to water contamination, which endangers local communities (Ma et al., 2014; Jaikawna and Pagdee, 2024).

CWS face internal and external pressures that threaten their sustainability, a common issue nationwide. Deforestation and water pollution from agriculture, including agrochemicals, harm the health and food sovereignty of communities (Hazlewood, 2023; Gómez-Mosquera, 2017; Montoya-Rendón et al., 2017).

The CWS studied aren't owners of demarcated lands, therefore, they cannot effectively monitor the conditions of the hydrological sources from where they supply the communities. Hence, we identify that the fourth principle is only partly met.

Graduating sanctions

CWS, failure to pay the service fee results in immediate water service disconnection. In contrast, in El Páramo and Santa Clara CWS no sanctions for non-payment were identified.

As a result, this principle is not universally applied across all CWS, as two of them lack clearly defined penalties for non-compliance with the collective management agreements.

There are easily accessible conflict resolution strategies

Most conflicts and disconformities between the management teams and the users obey increments in the fees, except for Santa Clara, where there is not a management team, and users do not pay for the service. In El Páramo CWS, the conflict resolution mechanism relies on a voting system during meetings. In Montebonito, they identify the subjects causing conflict and address them clearly and assertively during the meetings. In Naranjal, according to the users, disagreements between the management team and the beneficiaries aren't common. Hence, there is not a clearly established conflict resolution strategy in this CWS.

Results show that this principle is partially met, since Montebonito CWS is the only one where clear conflict resolution strategies were identified.

Commons present a legal status, hence the right to organize

Montebonito CWS stands out as the only case study to have officially established a public service supply company since 2010. In contrast, the other three CWS operate through existing local government structures like community action boards, without specific incorporation as public service suppliers.

The seventh principle is partially met by the CWS in Naranjal, Santa Clara, and El Páramo. Their lack of official supplier status results in inadequate institutional support, particularly concerning the financial and technical resources needed by both the organizations and the communities to ensure efficient service delivery in terms of quality, quantity, and frequency.

This situation echoes the Colombian context in general, as the current legal and institutional framework for CWS seems to be inadequate and limits the strengthening of water management (Quintana-Ramírez, 2008), as it does not consider the local social and political dynamics nor significant financial and technical limitations. Alternative suppliers fund the building and maintenance of the infrastructure via credit. The debt acquired increases in the face of the state's lack of support and constant marginalization. Thus, supplier organizations adopt market logics, which might have impacts on the service provided to communities as the fees increase (Ecuyer, 2022).

Commons are embedded within larger networks

This principle is met in all four cases, as they are embedded in various networks:

- CWS Alliances: The management teams of Naranjal and Montebonito CWS have an informal agreement so the first one would provide the service in the case of prolonged cuts.
- State Support: The Mayor's Office has provided materials (e.g., pipelines) to Naranjal and El Páramo CWS, and subsidies to Montebonito users. Department-level institutions have funded CWS for equipment (Montebonito) and ecosystem protection (Santa Clara, Naranjal, El Páramo).
- NGO Alliances: El Páramo CWS received support from the Pangea Foundation for paramo restoration. Montebonito's river basin restoration was supported by the Development Program for Peace in Magdalena Centro, while Scientific Colombia led an environmental education program. The Mayor's Office and Coffee Producers Committee helped Naranjal install septic tanks.

The seventh principle is partially met by CWS in Naranjal, Santa Clara, and El Páramo, as their lack of official status leads to poor institutional support, especially in financial and technical areas needed for efficient service in terms of quality, quantity, and frequency.

The results of the analysis of Ostrom's principles (1990) show that these are partially fulfilled in most cases. This could translate into the need to strengthen the structures that manage water communally in the upper Guarinó River basin, mainly through recognition, financial and technical support, and effective protection of watersheds and related ecosystems. Annex 3 summarizes the results obtained for the different principles studied.

Conclusion

This study of four Community Water Supply Systems (CWS) in the upper Guarinó River basin highlights that the difficulties faced by rural water systems in Colombia cannot be reduced to technical or managerial shortcomings. Problems such as declining water quality, environmental degradation, limited financial and technical capacity, and weak institutional recognition are closely connected to broader patterns of territorial inequality and to governance frameworks that place growing responsibilities on rural communities without providing adequate support.

In a national context where CWS supply nearly 40% of rural water services, community management should be understood primarily as a practical response to persistent gaps in state provision, rather than as a voluntary or alternative governance choice. The obligation for CWS to comply with regulatory standards originally designed for large-scale providers creates significant operational challenges and, in some cases, threatens their sustainability. In the Guarinó basin, water scarcity and contamination are better explained by hydrosocial dynamics (such as land-use change, agricultural expansion, and uneven territorial control) than by deficiencies in local management alone.

While community participation is often presented as a defining strength of CWS, the empirical findings reveal internal inequalities. Women, in particular, play a central role in both the daily operation and political management of water systems, often under conditions of work overload and limited institutional support. At the same time, processes of formalization intended to improve accountability may introduce new barriers to participation.

Policy approaches that focus mainly on technical assistance or managerial capacity risk overlooking these broader social and institutional dynamics. Strengthening community water systems therefore requires greater coherence between regulatory frameworks and the social, territorial, and organizational realities of rural communities. Legal recognition and institutional support should aim to reinforce the collective capacities and relative autonomy of CWS, rather than integrating them uncritically into standardized service provision models.

This study relied primarily on semi-structured interviews and document analysis within a small and geographically localized sample in the upper Guarinó basin, which limits the broader generalizability of the findings. Moreover, while gender dynamics in water governance emerged as an important analytical dimension, the study did not examine how class and ethnicity, in intersection with gender, shape participation, access to decision-making, and power relations within CWS. This constitutes an important limitation of the research, but also points to a critical avenue for future research. Understanding how socio-economic differentiation and ethnic identities intersect with gendered responsibilities could provide deeper insight into inequalities embedded in community water governance.

Future research should therefore expand geographically to include the middle and lower sections of the Guarinó River basin, enabling comparative analysis of water governance across the watershed. Additionally, incorporating participatory methodologies (such as community mapping, focus groups, and collective dialogues) would allow for a more nuanced exploration of intersecting social dimensions and help amplify marginalized voices. Finally, the integration of geospatial analysis and remote sensing techniques could provide robust evidence of land-use change, deforestation dynamics, and infrastructure distribution, thereby strengthening the empirical link between environmental conditions and water service provision outcomes.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving humans were approved by Ethics Committe of University of Caldas. 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.

Author contributions

AO: Formal analysis, Funding acquisition, Investigation, Methodology, Writing – original draft, Writing – review & editing, Conceptualization. MM: Writing – original draft, Writing – review & editing. FB: Writing – original draft, Writing – review & editing. HC: Conceptualization, Supervision, Writing – original draft, Writing – review & editing.

Funding

The author(s) declared that financial support was received for this work and/or its publication. This paper is part of the research project "Community water supply service systems in Caldas and Cauca paramo ecosystems as territorialities for peace" (originally "Los acueductos comunitarios en los páramos de Caldas y Cauca (Colombia 2018–2023) como territorialidades para la paz"). Supported by the Orquídeas 935 call from the Ministry of Science, Technology and Innovation, funded by the National Fund for Financing Science, Technology and Innovation, Francisco José de Caldas.

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

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/frwa.2026.1732846/full#supplementary-material

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