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Sustaining community-managed rural water supply systems in severe water-scarce areas in Brazil and Tunisia

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Abstract – In many countries, the challenge of sustaining rural water supplies is entrusted to community organizations, which have difficulties in performing durably the operation, maintenance and cost recovery of rural water supply systems. This paper analyzes how rural communities struggle to ensure a sustainable access to water, while seeking close interaction with outside actors such as the State, NGOs, and politicians. The analysis is based on field observations, interviews and participatory workshops in four community-managed water supply systems in Brazil and Tunisia. To sustain the access to water, communities limit their dependance on community-managed water supply systems and diversify water sources for different uses; they adapt the technical and organizational dimensions of water supply systems through *bricolage*; and use political leverage to obtain financial and technical support. Understanding how communities adapt the infrastructure and the organization of rural water supply, in close interaction with external actors, may inspire water providers in designing more resilient water systems.

Keywords: water supply / communities / adaptations / resilience / Brazil / Tunisia

Résumé – Durabilité des systèmes ruraux d'approvisionnement en eau gérés par les communautés au Brésil et en Tunisie. Dans de nombreux pays, l'approvisionnement en eau en milieu rural est confié aux organisations communautaires, qui éprouvent des difficultés à en assurer durablement l'exploitation, la maintenance et le recouvrement des coûts. Cet article analyse comment les communautés rurales luttent pour assurer un accès durable à l'eau, en sollicitant l'État, des ONG et des élus. L'analyse est basée sur des observations de terrain, des entretiens et des ateliers participatifs dans quatre communautés dans un contexte d'extrême rareté de l'eau au Brésil et en Tunisie. Pour maintenir un accès durable à l'eau, les communautés limitent leur dépendance à l'égard des systèmes collectifs et diversifient les sources d'eau pour différents usages ; elles adaptent l'infrastructure et l'organisation des systèmes collectifs par le bricolage ; et elles utilisent l'influence politique pour obtenir des soutiens des acteurs externes. Comprendre comment les communautés adaptent l'infrastructure et l'organisation de l'accès à l'eau, en étroite interaction avec les acteurs externes, peuvent inspirer les fournisseurs d'eau dans la conception de systèmes d'approvisionnement en eau plus résilients.

Mots clés : système rural d'approvisionnement en eau / communautés / adaptations / résilience / Brésil / Tunisie

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1 Introduction

The sustainable access to water for rural communities has been a persistent problem in many countries. From 1990 to 2015, rural coverage of piped water has increased from 62% to 84%. However, a significant disparity exists between rural and urban areas. According to the World Health Organization (2017), "*two out of five people in rural areas and four out of five people in urban areas now use piped supplies*". This is also the case in Brazil and Tunisia, where our study takes place. In Brazil, 93.9% of urban households are connected to reliable water services *versus* only 34.5% in rural areas (IBGE, 2014). In Tunisia, in urban areas, 99.8% of the population receive piped water compared to 65% in rural areas (INS, 2018). Nevertheless, beyond coverage, the challenge is to keep rural water supply systems (RWSS) working (Schouten and Moriarty, 2003). This explains the lively debate on the functionality of RWSS, in terms of both infrastructure and organization required to manage it (Whaley and Cleaver, 2017).

Since the International Drinking Water Supply and Sanitation Decade in the 1980s, community management has been promoted to facilitate lasting access to water, as previous top-down approaches that did not involve communities largely failed (Schouten and Moriarty, 2004). However, there is a growing feeling that too much has actually been asked from communities: "*part of the implicit appeal of the community-based management (CBM) concept for key development players (international donors, development organizations, and governments) is that it allows them to highlight a concern for sustainability whilst at the same time distancing themselves from much of the responsibility for delivering it*" (Whaley and Cleaver, 2017). In some cases, there was even an explicit objective of rendering communities autonomous and bypassing rural elite and politicians (Machado *et al.*, 2019). Yet, communities have consistently continued to mobilize external actors (the State, NGOs) when in difficulty, including through clientelist relations (Collard *et al.*, 2013). The debate has, therefore, increasingly focused on the coproduction of rural water supply, defined as "*an arrangement between State (or other supporting agency) and citizens for delivering (public) services*" (Hutchings, 2018).

While many authors agree that community engagement with RWSS has played an important role in improving the coverage of water supply in rural areas, there is a more critical debate on how communities fared in actually sustaining water supplies (Hutchings *et al.*, 2015). Critical problems for communities related to financing and cost recovery (Whittington *et al.*, 2009), the difficulty of designing "*resilient, affordable and reliable*" technology (González Rivas *et al.*, 2014; 573), the continued use of alternative water sources (Aleixo *et al.*, 2019), the lack of sustained external financial and technical support (Smits *et al.*, 2013), and organizational issues in the community (Hutchings *et al.*, 2015).

RWSS are often planned for domestic uses only, but communities also use water supplies for a wide range of productive uses around homesteads, including irrigation and livestock breeding (Renwick *et al.*, 2007; Smits *et al.*, 2010). Moreover, implementing agencies propose RWSS with the belief that the piped network will exclude all other water sources. Yet, local users maintain multiple sources, depending on: the seasonal water availability (Macdonald *et al.*, 2016); the water quality related to specific water uses; and the distance from the household and convenience of fetching water (Almedom and Odhiambo, 1994). When piped networks designed for human consumption do not match local expectations, they are converted to non-consumptive purposes in an unplanned way (Moriarty *et al.*, 2004). Unplanned uses can create a higher demand than the network can manage, may complicate the management and cause damage to infrastructure. Conversely, people with unreliable RWSS look for alternative water sources or make adaptations to infrastructure and organization (Elliott *et al.*, 2019). We argue that observing such adaptations, often made in close interaction with external actors, is an opportunity to understand how individual households and the community sustain access to water (Sweya *et al.*, 2021).

This paper analyzes how rural communities, in interaction with outside actors (the State, NGOs, politicians) struggle to ensure sustainable access to water. In this paper, RWSS are analyzed as systems: catering to multiple water uses; that depend on one or more water resources; that include water infrastructures and the organization managing them; that are embedded in social relationships, within the community and with external actors, that have contributed to its establishment and development. This article is not about "saving" the community-managed model (Whaley and Cleaver, 2017), but about the fact that engaging a meaningful practice-based dialogue with rural communities about water supply provides valuable lessons for implementing RWSS.

2 Study areas and methodology

2.1 Four case studies in water-scarce contexts

Our analysis is based on four rural communities in the Northeast of Brazil and in Central Tunisia. These communities all have a problematic access to water, but the socio-political context, affecting the way rural water supply is arranged, is very different. While in Ceará (Brazil) there has been a diversity of public and private actors involved in rural water supply (State agencies, NGOs, large-scale breeders – *fazendeiros*) in a context of clientelism and land inequality (Collard *et al.*, 2013), in Sidi Bouzid (Tunisia) there is basically a relation between the community and the State, which provides the financial and technical support to RWSS, mediated by local elite; nevertheless, the 2011 Arab Spring has changed the power relations among the three parties.

2.1.1 Varzea do Meio and Serra Santa Maria Communities (Ceará, Brazil)

Varzea do Meio and Serra Santa Maria are two communities in Quixeramobim municipality (Ceará), located in the region most affected by droughts (Fig. 1).

Agriculture in Quixeramobim is characterized by the coexistence of large cattle ranches (*fazendeiros*) and subsistence farming (*e.g.*, corn and beans) with small-scale animal husbandry (*e.g.*, poultry, cow, goat, pig). Farmlands are often fragmented and located around the river with limited irrigation. The climate is characterized by two seasons: the rainy season

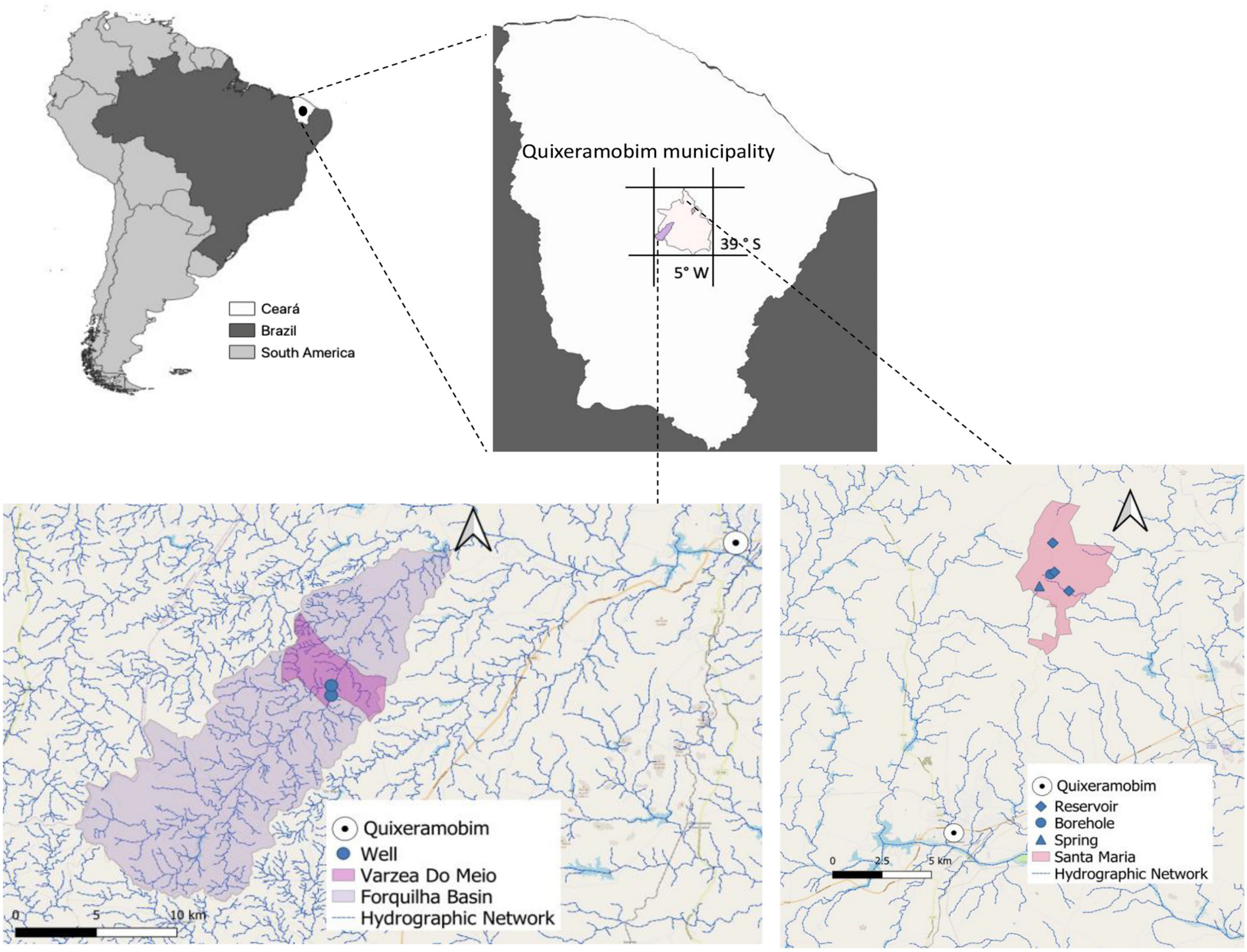

Fig. 1. Location of the Varzea do Meio and Serra Santa Maria communities, Ceará, Brazil, South America (Source: FUNCEME, author).
Fig. 1. *Localisation des communautés de Varzea do Meio et de Serra Santa Maria, Ceará, Brésil, Amérique du Sud.*

from February to April and the dry season from May to January. Quixeramobim is located on a massive crystalline basement, meaning that groundwater exploitation requires expensive drilling and yields saline water (Burte *et al.*, 2009). The Varzea do Meio community (19 km^2) is composed of 90 families. It is located in the Forquilha valley (mid hill area) with an average rainfall of 750 mm/year. Rainfall is extremely irregular in terms of frequency and intensity. Three water resources are used for domestic and agricultural use: surface water reservoirs, alluvial aquifers and cisterns, a centerpiece of a rainwater harvesting system from the roof of houses. Reservoirs are located in the upper catchment, while groundwater is essentially used in the lower catchment for irrigation, cattle watering and domestic uses (Burte *et al.*, 2009). The Serra Santa Maria community (22 km^2) is composed of 31 families. Located in a hilly area, it presents a diversity of land ownership status, shaping water resources and uses. The agrarian reform association possesses two small collective reservoirs for all uses, individual cisterns for drinking and cooking, and shallow dug wells for domestic uses. *Fazendeiros* use their own reservoirs, springs or wells, which are shared with their workers, who own neither the land nor the homestead. Some small landowners have individual water infrastructures. Water from cisterns or wells is shared with family members and neighbors, especially for drinking and cooking.

2.1.2 Ouled Salah and Ouled Om Hani communities in Sidi Bouzid, Tunisia

Rihana district (90 km^2) in Central Tunisia (governorate of Sidi Bouzid) (Fig. 2) is among the most environmentally and socio-economically vulnerable areas of the country. Average rainfall amounts to 200 mm/year. Rainfed olive and almond trees dominate the landscape; irrigation is limited to rich inhabitants with private boreholes. The RWSS in the Ouled Salah community (120 families) in South Rihana and in the Ouled Om Hani community (200 families) in North Rihana only cater to part of the households due to dispersed habitat.

In these communities, there is considerable heterogeneity of households in water access and water uses (Morardet *et al.*, 2020). Some households are connected to the RWSS and store water in cisterns for domestic use, for vegetable gardens irrigation and for livestock watering. Most households have

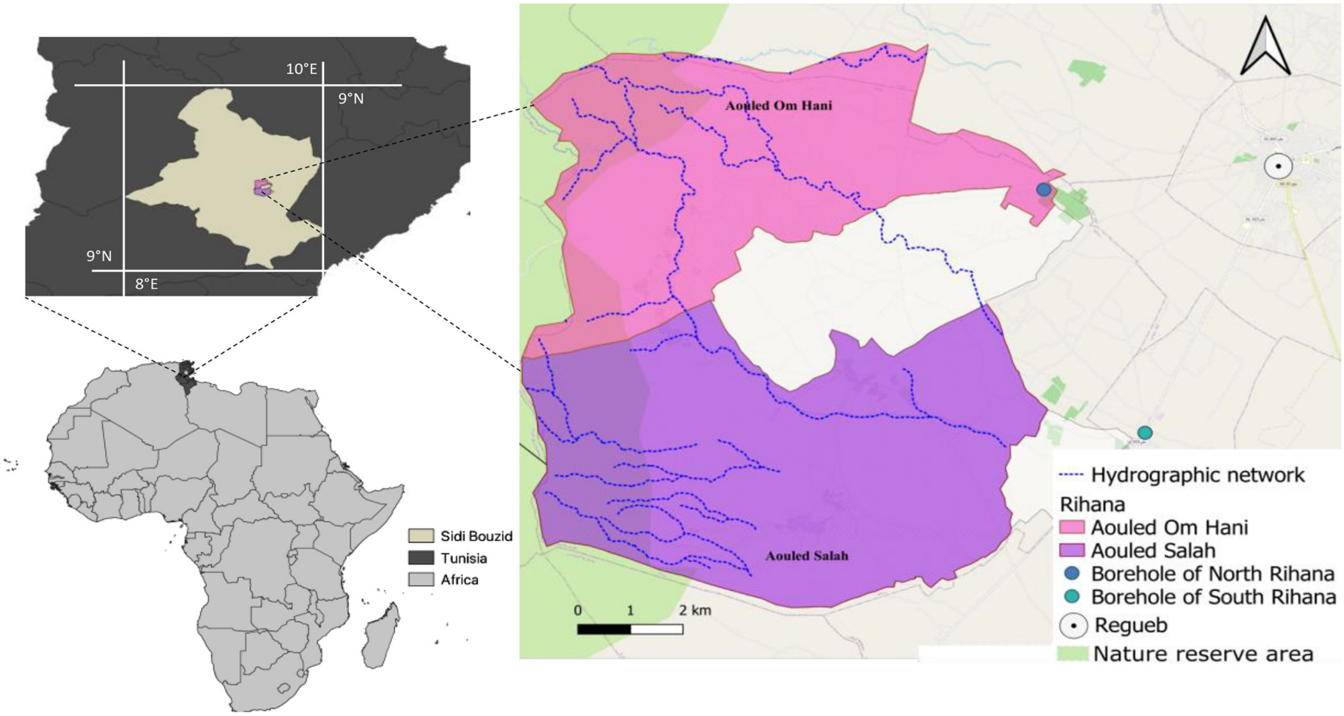

Fig. 2. Location of the Aouled Om Hani and Aouled Salah communities in Rihana, Sidi Bouzid, Tunisia, Africa (Source: Agricultural map of Sidi Bouzid, author).

Fig. 2. *Localisation des communautés d'Aouled Om Hani et d'Aouled Salah à Rihana, Sidi Bouzid, Tunisie, Afrique.*

rainwater collection tanks for drinking and cooking. Others, not connected to the RWSS, have built two cisterns, one for rainwater harvesting (for drinking and cooking) and the other for storing water from tanker trucks purchased from private wells (for other uses). Wealthy households also have private boreholes for irrigation, which can be used for domestic purposes if necessary.

Local leaders are key actors to mediate relations with the State on the investment, cost recovery, operation and maintenance of the RWSS.

2.2 Data collection and analysis

First, we reviewed existing literature, including unpublished documents, maps and reports. Second, we conducted a participative diagnosis on people's living conditions and water issues and selected the communities for our case studies (Tab. 1); four communities were chosen, reflecting a diversity of situations: water services (individual, collective), community organization (with active association, without association), and type of water resources (surface and groundwater) and infrastructures (collective and individual networks, wells, storage dams and cisterns). Third, we undertook a historical analysis of the trajectory of the RWSS in the different cases through participant observation, developing live narratives and semi-structured interviews with key stakeholders (Tab. 1). Fourth, we undertook surveys to analyze the functioning of the RWSS over a period of three years (2019–2021) on the following themes: the water actors, the different uses, the infrastructures and resources, the rules of use, and the technical and organizational adaptations made. Fifth, once a relationship of trust was established with local actors, we organized workshops in each study area to co-design conceptual models, representing the trajectory of RWSS, involving community members with a diversity of gender, age and water supply systems (Tab. 1). The conceptual model was inspired by the local development paths approach of Sabourin *et al.* (2004), which is useful to represent social and technical transformations of rural societies allowing a more generic character to the results obtained in each case study. We applied this approach to RWSS, in particular to the transformations in the infrastructures, the rules-in-use, the type of water resources used, and the water users and their uses. We used simple symbols for these different items to co-design the trajectory of RWSS with community members.

3 Results

3.1 Trajectories of RWSS in two communities in Ceará, Brazil

3.1.1 Santa Maria: a community RWSS born again?

The case of Santa Maria shows the many problems faced during implementation of a community-based RWSS with an extremely heterogeneous community. Despite several breakdowns and even a collapse, the community remains interested in the community RWSS, looking for collective solutions with outside support.

We went back to more than 50 years ago. Before the 1970s, there was a plurality of water sources in this mountainous area,

Table 1. Overview of different methodological steps and tools used for data collection and analysis.
Tableau 1. *Aperçu des différentes étapes méthodologiques et des outils utilisés pour la collecte et l'analyse des données.*

Steps	Methods
1 Literature review	– Review of relevant academic articles, reports and associated documents – Use of existing data from maps, reports and similar sources
2 Selection of case studies	– Participatory diagnosis – Participatory mapping
3 Historical analysis of RWSS trajectory in selected case studies	– Participant observation – Life narratives – Semi-structured interviews (15 in Tunisia and 20 in Brazil; individual and group interviews; virtual and in-person meetings) with key stakeholders: community health agent, water users' association members, district engineers, and local water technicians.
4 Analysis of the functioning of the RWSS	Surveys (30 in Tunisia and 40 in Brazil) to collect information at the household and community levels on: – Water users – Water uses (drinking, domestic, agricultural) – Infrastructures (lay-out, quality, location) – Resources (quantity, quality, location) – Rules of use (formal and informal) – Evolutions and adaptations in infrastructure and rules
5 Co-design of RWSS trajectories  	Participatory modeling: using a conceptual model as a discussion support **Workshops in Tunisia and Brazil** **Tunisia:** – 10 interviews to prepare the workshop – 1 workshop mixing both communities (Ouled Salah and Ouled Om Hani) – 12 participants: 4 women and 8 men (6 from Ouled Salah and 6 from Ouled Om Hani communities) **Brazil:** – 12 interviews to prepare the workshops – 1 workshop in Santa Maria community – 8 participants (4 women and 4 men) – 1 workshop in in Varzea do Meio community – 8 participants (4 women and 4 men)

including springs and shallow dug wells along water courses (see Fig. 3). Some were intended for specific uses, while most shallow dug wells were used for multiple purposes. The flows of the sources depended on the season (wet or dry) and on the year. The cost of maintaining the sources was low, and there was a lot of solidarity among local inhabitants to provide water access when sources dried up.

State intervention to deal with water scarcity from the 1970s to the 1990s, linked to the fear of massive rural migration to cities, focused on technical fixes. Shallow dug wells were converted to wells and two small surface water reservoirs were built. These reservoirs were meant to serve all inhabitants, but in practice they were privatized by large landowners, as they had been constructed on their land. The focus of public policies from 2000 onwards was on poverty alleviation, and in Santa Maria a large farm was expropriated for the benefit of landless residents through agrarian reform. This implied they had to carry out farming operations through imposed collective action. The State provided them with training and material to construct cisterns, along with a water harvesting system from house roofs (Fig. 4). The cisterns were located next to the houses and reduced the drudgery of water fetching. However, this did not solve the problem of water scarcity and, especially during the dry season, water was still provided from outside by trucks.

In 2008, the State and NGOs constructed a community RWSS, including a pump, a water tower and taps. The RWSS was connected to the existing reservoir, situated on the expropriated large farm, and was to be managed by the agrarian reform association. The initial beneficiary group also included 10 additional households. However, the association decided to restrict the RWSS to its members' households, because the reservoir could not meet the demand of a network

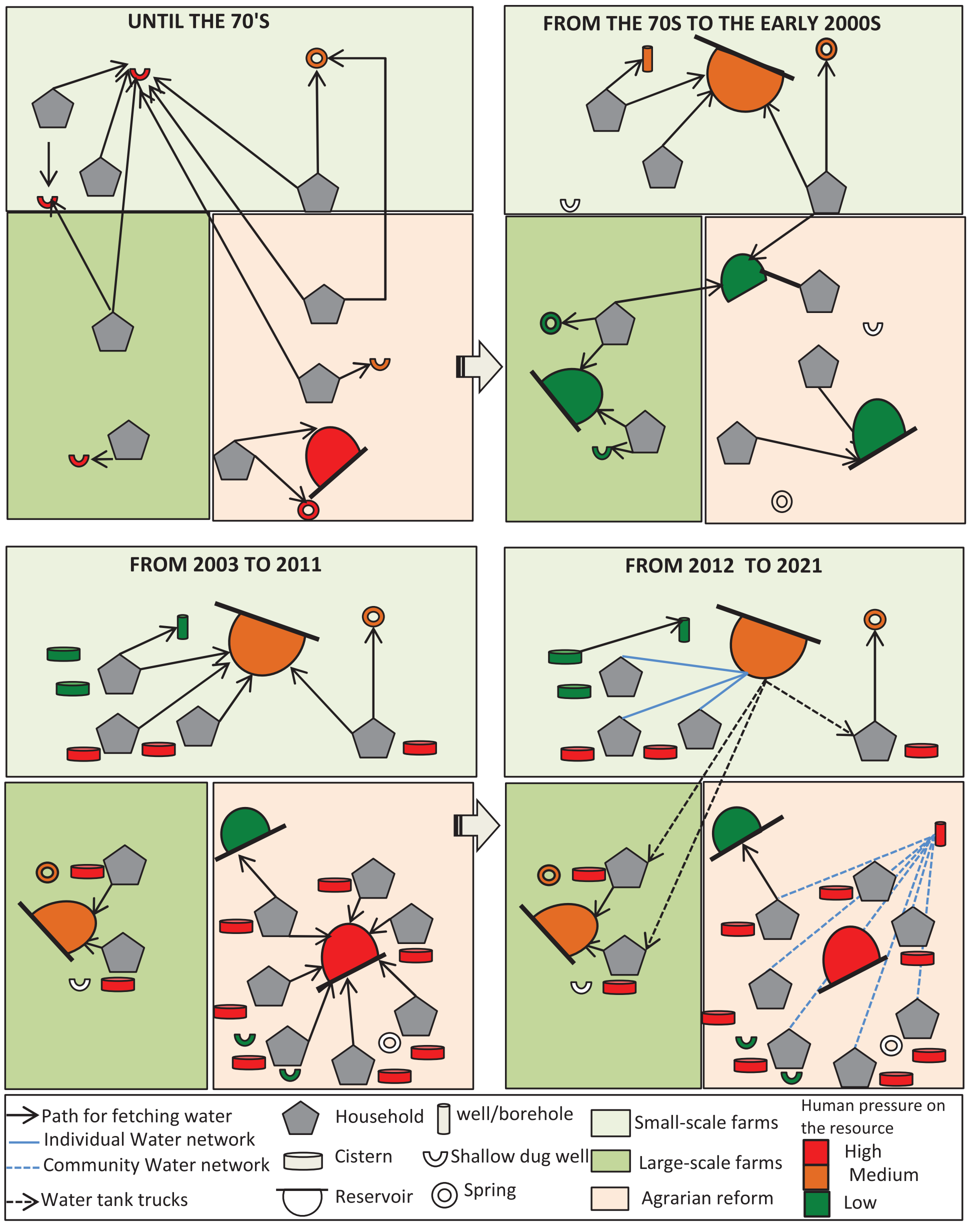

Fig. 3. RWSS trajectory in Serra Santa Maria community.
Fig. 3. *Trajectoire du système rural d'approvisionnement en eau dans la communauté de Serra Santa Maria.*

designed for domestic purposes and also be used for watering gardens and animals during the dry season.

The operation of the RWSS began in 2012 but stopped in 2016. Many factors were responsible for its collapse. First, the network was developed while the residents split up the collective farm, turning away from what they felt as imposed collectivism. The president of the association looked for work outside during the drought (2012–2017) and, when he quit his position in 2016, no one took over the responsibility. Then, in an uncontrolled slash-burn of his land, a farmer burned the electrical wires powering the floating pump, and the association did not have the financial means to replace it.

Second, the inhabitants lost interest in the provided services. They had expected a big change in their lives with the provision of tap water, but were disappointed by the high price for untreated water, available free of charge elsewhere. Also, the reservoir dried up three years after installing the network, reinforcing the perception that it was not a sustainable response to droughts. The exclusion of small farmers not being members of the agrarian reform association caused a division in the community and weakened the ability to cope with droughts. There was another plan to restart the community RWSS in 2018 with the installation of a borehole on the land of the president of the association. However, the energy costs for operating the borehole were too high and only the president's household used it.

From 2016 to 2020, the community members used a diversity of water supply systems. Large landowners with financial means built their own infrastructure (reservoir, motor pump, storage tank and taps) along with rainwater cisterns. Small landowners used rainwater cisterns, which were filled for free by tanker

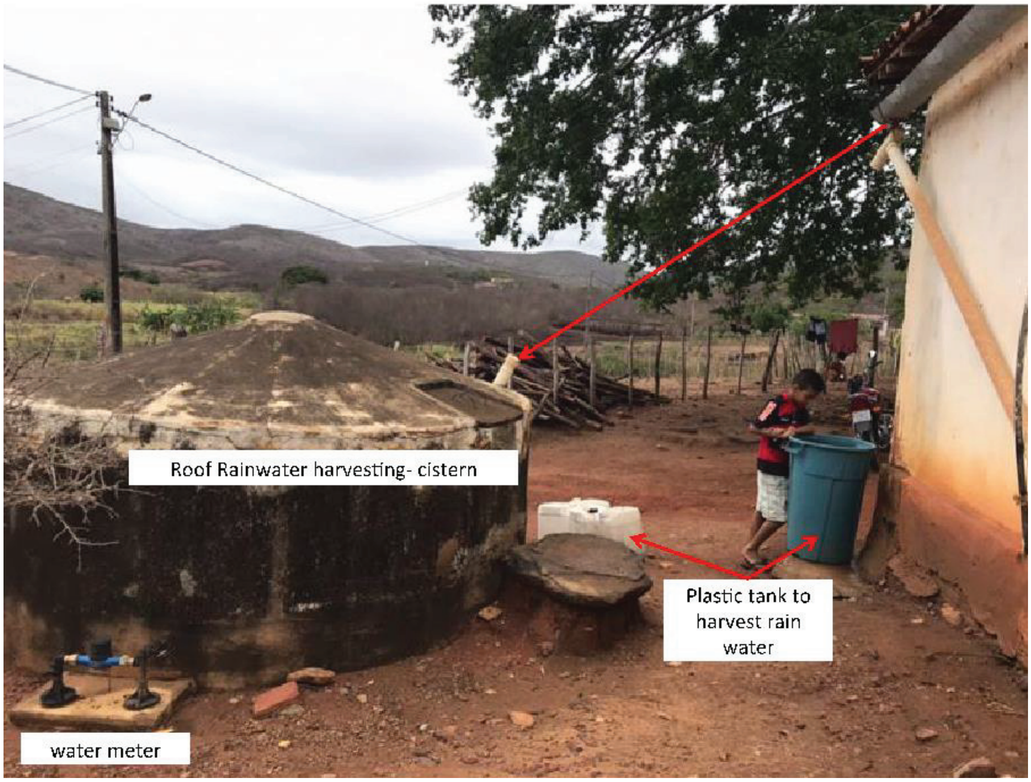

Fig. 4. A typical backyard in the Serra Santa Maria community with a cistern and plastic tanks (Author, 2020).
Fig. 4. *Une arrière-cour typique de la communauté de Serra Santa Maria avec une citerne et des réservoirs en plastique.*

trucks from the large landowners' reservoirs. The trucks were contracted by the Federal Government, while the landowner aimed to maintain good and multiple (family, business and labor) relations with community members. Members of the association used rainwater cisterns, collected water from two collective reservoirs in the rainy season, and received tanker trucks in the dry season. Yet, they kept the water meters of the RWSS intact in the hope that maybe one day they could use them again (Fig. 4). In 2021, the reservoirs of the agrarian reform association dried up, forcing the inhabitants to think of a collective solution. They received water from tanker trucks every month to fill their cisterns from the large landowner's reservoir. For domestic water, they contacted the community advisor to reactivate the RWSS based on the existing borehole. In April 2021, the community received a storage tank with taps, where residents who are not connected to piped water could buy water in a bucket. A meeting with the inhabitants to identify the beneficiaries and the purpose of this new infrastructure, financed by the municipal authority, was planned but never happened. The storage tank is currently used by all members of the association, who shared the costs for the renovation of the water pipes and a new water pump. Faced with the poor quality (salinity) and high energy costs of this new RWSS, the beneficiaries hope to obtain solar energy and a desalinator to improve their situation.

3.1.2 Várzea do Meio: a failed design but appropriation through collective adaptation

To this day, the main factors that have kept the community-based RWSSs functional, despite the limited number of water sources in Varzea do Meio, are the good political connections of the community and the active community water association.

During the first period (1950–1998), the water was mainly supplied from the river (Fig. 5). Originally the community was based on three families and a few scattered houses, and the water supply was organized through three shared shallow dug wells for human consumption and three additional small shallow dug wells for watering cattle. There were a few private wells for domestic use.

External interventions (Federal Government, Ceará State, NGOs, and International Donors) on the water supply system started in the 1990s. The community received five collective water cisterns, each supplying ten families. During the dry season, they were filled by tanker trucks and reserved for drinking water. The river water was used for all other purposes. Then the community received electricity and the municipal authority implemented a pilot project to install boreholes in the region. The municipality financed the drilling equipment and the community provided labor force. The water availability and a sense of abundance prompted inhabitants to practice intensive irrigated agriculture. As a result, shallow dug wells were abandoned as the population considered that the surface water was polluted by chemicals (fertilizers and pesticides). In 2008, all boreholes dried up and the communities turned to use wells located in the riverbed (Fig. 5). These wells were deepened during the multi-year drought (2012–2017). However, access to groundwater depends on its recharge from surface water releases from small reservoirs located upstream in the watershed. The community has thus become dependent

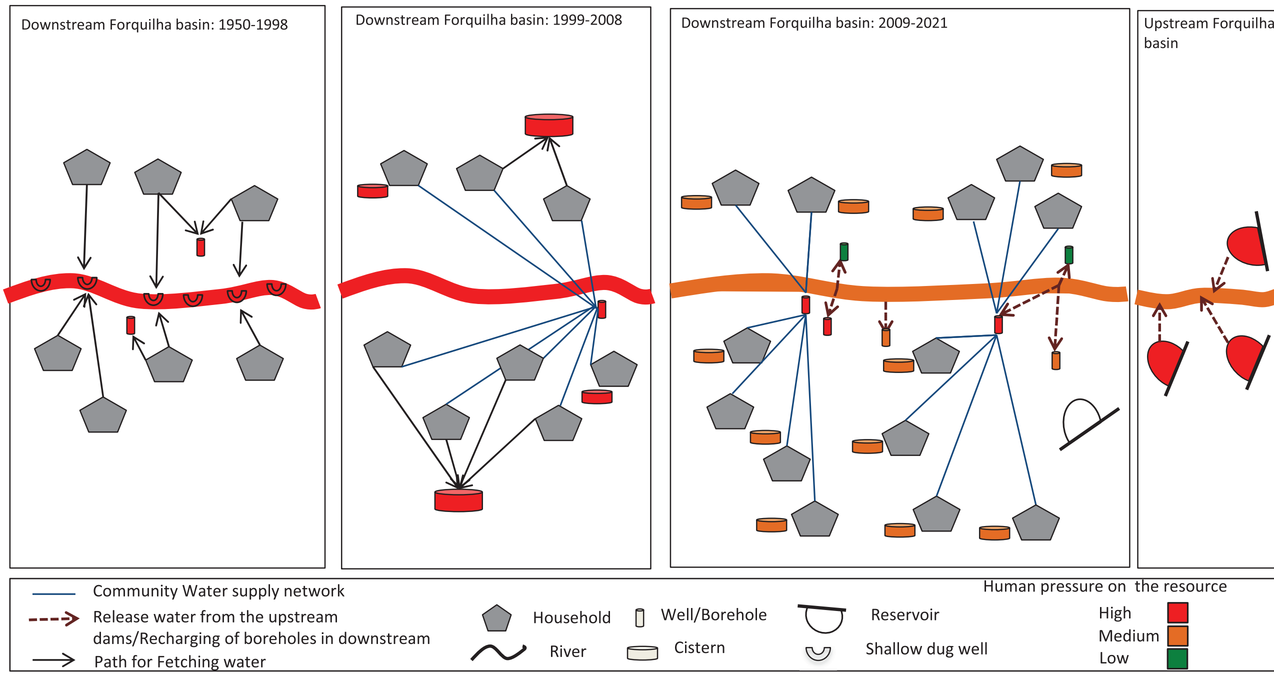

Fig. 5. RWSS trajectory in Varzea do Meio community.
Fig. 5. *Trajectoire du système rural d'approvisionnement en eau dans la communauté de Varzea do Meio.*

on upstream communities to release, or not, water. In 2017, almost all households had individual cisterns for drinking, abandoning the collective cisterns. From 2017 onwards, the community was supplied by two RWSS and individual cisterns. The first RWSS supplies thirty houses through the private well of a community resident, for which the residents pay only for electricity. The second RWSS supplies sixty houses from a well belonging to a large landowner who lives in town. The beneficiaries pay a fixed fee for the rent of the well and electricity fees. In the meantime, a few households created their own access to water, but the majority of the community looked collectively for a cheaper solution. In 2018, the community benefited from the construction of a State-funded reservoir. The reservoir will replace the private well, even though it is not yet supplying the collective water network due to the multi-year drought in the area.

3.2 Trajectories of RWSS in two communities in Rihana (Tunisia)

There has been a long litany of State interventions, often financed by international donors, in the community managed RWSS in Rihana. As it was designed for only part of the households, those excluded regularly attempted to join. This resulted in several illegal connections, which were then regularized and integrated in the RWSS, leading to the physical breakdown of the system and prompting, in turn, State interventions to upgrade the infrastructure. Yet, the RWSS has never been able to provide access to all community members. Currently, another international donor-financed project is underway in the study area, offering the opportunity to finance the rehabilitation of both North and South Rihana RWSSs. Drinking water cisterns are also built in North and South Rihana for the most disadvantaged households. The population is asking for wells for supplementary irrigation, but this is unlikely to be accepted in a context of groundwater overexploitation. Community members are still in a strategy of expansion of water use in a severely constrained environment. Tensions are likely to continue and pressure on the community system will even increase, preparing for further breakdowns to come.

The trajectory of the RWSSs in Rihana is problematic. Before 1980, the community collected rainwater in a collective basin and diverted flash floods to irrigate agricultural lands. The community fetched water from the collective basin by private tractors or through 500-liter tanks fixed on donkey carts. Water access was reinforced by a well in South Rihana in 1980 from which people fetched water on foot, with animals or by hiring a private transporter (Fig. 6).

Since the 1970s, the seasonal migration of men to the coast and to Libya has led to a change in living standards and in expectations towards water services and water quality. In 1999, rural development programs were implemented to provide electrification, and the well got replaced by a borehole, standpipes and public taps. The infrastructure was then entrusted to a community association and no longer managed directly by the State. However, the association lacked human, financial and technical resources and the State continued to interfere in the borehole management, often at the request of the dissatisfied inhabitants. The borehole was insufficient to supply the whole of Rihana and in 1999 the State decided to build an additional borehole to supply North Rihana, while using the existing borehole only for South Rihana. The new borehole was initially planned to be located next to the existing one, but inhabitants of North Rihana asked that it be installed near their houses, in a place where water is less salty.

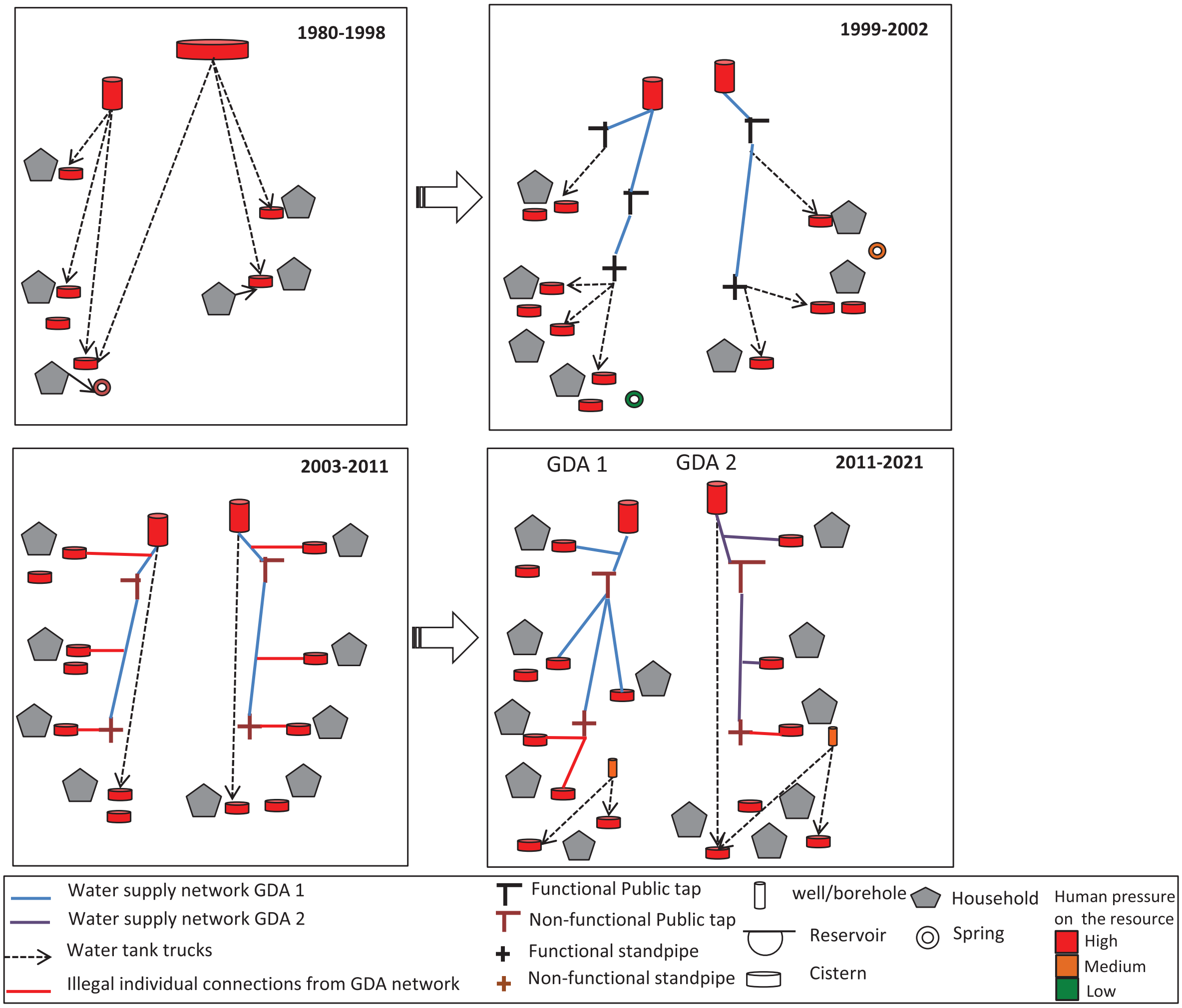

Fig. 6. RWSS trajectory in Rihana (GDA 1 in South Rihana; GDA 2 in North Rihana).
Fig. 6. *Trajectoire du système rural d'approvisionnement en eau à Rihana (Groupement de développement agricole [GDA] 1 au sud de Rihana, GDA 2 au nord de Rihana).*

From 2003 to 2011, the inhabitants, who had standpipes near their houses, transformed them into private taps. The other inhabitants, thus excluded from the RWSS, made illicit connections on the pipes (Fig. 6). To control illicit connections, user contracts have been established and the majority of people were thus able to join the agricultural development group (GDA), manager of the RWSS (2007–2011). The rest of the community had to buy water from the GDA borehole, transported by towed tanks.

In the aftermath of the Tunisian revolution in 2011, the number of illegal connections of non-members of the GDA increased. This caused numerous dysfunctions, frequent interruptions in water distribution, and conflicts. The non-payment of water bills caused the indebtedness of the GDA. The GDA had thus grown progressively into an unmanageable entity. In 2011, the GDA was split in two, a second GDA being created in North Rihana. This RWSS was initially composed of 25 public taps and five standpipes. However, residents wanted individual access to water and established illegal individual connections. In South Rihana, 180 families are connected to the RWSS, while there are still 30 families not connected. In North Rihana, 300 families are connected to the RWSS, while 300 more families are still waiting to join.

The individual connections resulted in reduced water flow and pumping failures. The GDA president explains "*Due to illicit connections, the water supply network is out of control... Theoretically the water volume pumped from the well is sufficient to supply the entire region of South Rihana, but these illegal connections do not allow this* [...]" (interview conducted in January 2021). Between 2009 and 2020, the borehole of South Rihana was replaced three times for technical reasons by the State, although this was theoretically the responsibility of the GDA.

Today the population of South Rihana uses water from the network for domestic use, livestock watering and irrigation: "*No one drinks GDA water. This water is only used for domestic purposes or to irrigate some olive trees in the backyard of the house. The standard of living in the area has evolved and the inhabitants want to drink very good quality water, mineral water or rainwater* [...]" (Interview with the GDA president conducted in January 2021). Due to the high frequency of outages, the population with access to this RWSS stores water in semi-buried cisterns when water is available. People also harvest rainwater, stored in semi-buried cisterns (different from those used for GDA water), for drinking and cooking.

In North Rihana, the GDA water is used for all purposes including drinking and cooking. However, the GDA distribution network cannot satisfy all demands and inhabitants buy water from private boreholes or from the GDA borehole through tanker trucks.

4 Discussion and conclusion

Our analysis of water supply systems in four very difficult contexts showed how rural communities ensured sustainable access to water for multiple uses, including drinking water, domestic water, irrigation and livestock. In keeping with the idea that communities cannot be solely responsible for doing so (Hutchings, 2018), we analyzed community actions in their interactions with external actors, including politicians, NGOs and the State. Our results qualify, first, the importance of a collective rural water supply system for the community. Drinking water is, in all case studies, provided for outside of the RWSS, through individual water harvesting on house roofs or through deliveries by public or private tanker trucks, and stored in cisterns. Indeed, the water quality delivered through the RWSS generally does not fit for drinking, which would require substantial investments (Collard *et al.*, 2013).

Also, community members do not want to be totally dependent on RWSS and keep other water sources active. This shows, second, the ambivalent relation that communities have with community-managed RWSS. The collective system was abandoned (in Santa Maria, Brazil); considerably modified by the community because it did not respond to their needs (in Varzea do Meio, Brazil); or even partially destroyed by the population not satisfied with the service provided (in Rihana, Tunisia). Yet, in all cases, the communities made considerable effort to keep the RWSS functional and never gave up on it. For example, in Santa Maria, inhabitants kept the water meters of the collective system, even when the system had stopped to function; five years later, the RWSS was gradually pieced together again.

Third, in all case studies, communities entertained close relations with external actors to ensure access to water. These interactions concerned emergency services like the tanker trucks (in all case studies) and the RWSS itself. In Varzea do Meio, political networks were mobilized to install a dam to change the main water source from groundwater to surface water, while in Rihana the community would contact the State, through influential members of their community, to step in and handle, for example, the arrears of members in the electricity bill or to rehabilitate the RWSS when the infrastructure became too degraded. This raises questions about the strategy of the State and the funding agencies, aiming to eliminate intermediaries and political figures from local development projects (Collard *et al.*, 2013). More generally, the question then is: when the academic community, practitioners and community members all understand the limits of community-managed RWSS, why do we still engage in developing such projects without an explicit coproduction lens (Hutchings, 2018)?

The fourth issue is how to define a community of water users. In Santa Maria, members of the agrarian reform association excluded other small farmers when the RWSS was not sufficient to meet all water demands. In Rihana, membership was determined at the project stage in an opaque interaction between the State, the funding agency and the community. Whenever the RWSS was upgraded, new households would be included, particularly those that had already created an illicit connection on their own. The crux of the matter is that these projects have always been poorly designed, excluding a large number of households, which would then become part of the network, which was not designed to handle this influx. This is symptomatic of water projects that remained focused on infrastructure design and implementation with little attention to existing water uses, community dynamics, and how the network would be managed (Smits *et al.*, 2013).

Fifth, even though we advocate decentralizing the focus on hardware, the design of adequate technology remains an important issue. This relates in the first place to the agreement with the community on the standards of water services (water quality, cost) to expect. Such design choices were rarely discussed collectively. In all case studies, the RWSS was designed for drinking water but without ensuring the corresponding water quality. The network was, therefore, exploited for multiple uses (basic domestic uses; irrigating the vegetable gardens; watering livestock), leading to a higher demand for water and pressure on the collective system, resulting in disruption of services, conflicts, and in some cases voluntary degradation of the network. Also, water providers failed to build on local knowledge about the inter- and intra-annual variability of water resources leading to disruptions in the RWSS.

Sixth, communities kept their RWSS functional by engaging in institutional and technical *bricolage* (Whaley and Cleaver, 2017). Institutional *bricolage* related, for instance, to the inclusion of new members of the community, out of solidarity or simply to avoid degradation of the network by excluded users (Rihana), or conversely, the exclusion of certain users (Santa Maria); this, then, necessitated to adapt the rules-in-use for water distribution, payment and maintenance and, as explained by Cleaver (2017; 34) to legitimize these rules and imbue them with authority. Technical *bricolage* was about changing the main water resource (Varzea do Meio) or adding semi-underground cisterns to deal with frequent outages of the RWSS (Rihana). Through technical *bricolage*, the communities challenged the initial design (and the underlying assumptions) of the RWSS for which they were often not consulted, including their needs in terms of water quality, quantity and delivery. Indeed, for technology to function, it is important that users can challenge and adapt it (Akrich *et al.*, 2002). However, not all *bricolage* is aimed at sustaining the RWSS, as shown by: 1) the privatization of public taps in Rihana by individual households not satisfied with the standards of the collective system, or 2) the community members investing in alternative water infrastructure so as not to rely solely on the collective network. Keeping the RWSS at the center of the community's interests is hard work and will ultimately determine whether it remains functional.

In the international literature there is a strong focus on expanding the scope of managing rural water supply (postconstruction) beyond, but not without, the community (Whaley and Cleaver, 2017). However, in the cases we studied this policy change has not yet been operationalized. In several municipalities in the State of Ceará (Brazil), an NGO, supported by the State-owned Water and Sewage Company, is now entrusted with the management of such RWSSs, while coordinating with the presidents of water users' associations. Yet, there are many difficulties in making this work in isolated or sparsely populated areas. In Tunisia, a new water law has been under discussion to entrust municipalities with the responsibility to manage RWSS. The parliamentary debate has discontinued for the time being and there are no details available on the technical, organizational and financial consequences of such a transfer. In the midst of profound organizational changes (to come), we argue that the notion of coproduction whereby the community and external actors come together for the design, the construction and the management of the RWSS will remain important.

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