

The spotted zebra: Cohabitation between informal solutions and public-owned infrastructures for water supply in the Rio de Janeiro Metropolitan Region

Antonella Maiello^{a,b,*}, Ana Lucia Nogueira de Paiva Britto^c
and Suyá Quintslr^b

^a*De Colignystraat, 67, 2628HB Delft, The Netherlands*

^b*Instituto de Pesquisa e Planejamento Urbano e Regional, Universidade Federal do Rio de Janeiro, Rio de Janeiro, Brazil*

^{*}*Corresponding author. E-mail: antonella.maiello@gmail.com*

^c*Programa de Pós-graduação em Urbanismo, Faculdade de Arquitetura, Universidade Federal do Rio de Janeiro, Rio de Janeiro, Brazil*

Abstract

In many emerging and developing countries hybrid systems, not completely public nor private, have become a regrettable unstandardized ‘standard’ for water and sanitation service (WSS) provisions. These spotted zebras deserve the attention of both the scientific community and policymakers being ambiguous solutions. On the one hand, the hybrid systems allow broadening the access to the water supply service in face of the challenge to manage, maintain and adapt large infrastructures in a time of increasing climate change impacts, water-supply demand and drinking water scarcity. On the other hand, by embodying informal artefacts and unregulated behaviours to use natural resources, the hybrid systems enhance the vulnerability and precariousness of the population that is normally not reached by the formal public infrastructure. The paper presents findings of research conducted in *Queimados*, in the Rio de Janeiro Metropolitan Area. Our study suggests that grassroots solutions, albeit being an opportunity when integrated, represent a threat when standing alone, and it is critical to further discuss ways to promote such integration within a structured institutional public framework. Conclusions stress the need to rethink the grassroots engagement within socio-technical transition emphasizing the nexus between political culture, civic education and infrastructural solutions.

Keywords: Hybrid systems; Informal solutions; Rio de Janeiro; Socio-technical systems; Water supply

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Highlights

- We explored a hybrid system for water supply in the Rio de Janeiro Metropolitan Region.
 - We conducted in-depth field research developing both a survey and semistructured interviews.
 - We found opportunities related to a micro-scale water supply system, but threats associated to the informality.
 - We stress the importance of developing nexuses among publicness, education and infrastructures.
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Introduction

Three main models of water service provision have prevailed in the last century: public, market-based and community-based. These three models have alternated, each one gaining its own momentum as the recommended solution at different times and places (Meinzen-Dick, 2007). Nonetheless, the success of a model in one region would not assure an equal result in another. In practice, especially where the institutional framework is weak and vulnerable, the three models are not alternatives but are rather hybridized (Jensen & Wu, 2017). Natural, technical, but also political and institutional conditions create different contexts with specific needs, demanding different models. The natural distribution of water is not equal all over the world, but since ancient civilizations, humans have been able to implement techniques to take water where there is none. The so-called *qanat*, *kanat* or *karez* in Asia, and *khattara* or *foggara* in northern Africa are typical examples. They represent a sustainable and ancient grassroots-based system that has been currently abandoned, not for technical but for social and economic reasons (Wessels, 2008). These examples show that the implementation of technical solutions is determined by social and political factors. For this reason, scholars started to refer to water and sanitation services (WSS) as socio-technical systems (STS) (Guy et al., 2010). STS are technical devices, socially produced, and geared to meet specific human community needs. We relied on this theoretical perspective for this research, part of the DESAFIO project, a UE 7th Framework Program about the democratization of WSS in Latin America¹. In this paper, we understand *grassroots solutions* as informal and popular bottom-up arrangements, and not in the sense of an organized movement. Moreover, here we use this term with specific reference to the water supply.

In practice, in the realm of water policy and governance, especially in developing countries, the water service provision has increasingly strayed away from the three theoretical models. The hybrid systems are not a fourth alternative path. Instead, they are a mixture of all three mainstream models and arise from adaptations of socio-technical systems to the failures of these models. That is why we employed the metaphor of a spotted zebra to outline the hybrid systems. Without the stripes, the genetically mutated animal becomes more vulnerable to the environment than the others.

This outlier appearance and peculiar vulnerability symbolize effectively the water supply system we explored in the Rio de Janeiro Metropolitan Region (RJMR). Hybrid systems for water provision have different understandings among scholars. For instance, to Jensen & Wu (2017), it entails a kind of institutional innovation for service providers which blends the regulative agency model and the model based on private contract. To Ahlers et al. (2014), a hybrid system is a co-product of a conflicting and tense process of articulation among socio-political, biophysical and infrastructural drivers, caused by unequal power structures. To Furlong (2010), this kind of ‘infrastructure coexistence’ is the effect of inefficient

¹ <http://desafioglobal.org>

public services. Nonetheless, while analysing the case of Quibdó (Colombia), the author acknowledges that coexistence between grassroots solutions (in this case rainwater collection) and public utility service is better than the replacement of STS. Differently, authors such as [Joshi & Moore \(2004\)](#) envision the hybrid system as a co-production, that is, as a collaborative process between state and non-state actors. [Ostrom \(1996\)](#) first introduced the term ‘co-production’ to describe ‘the process through which inputs used to provide a good or service are contributed by individuals who are not in the same organization’ (p. 1073) including individuals as well as public or private institutions. At that time, Ostrom was defending the importance of the engagement of multiple institutions in the governance of the commons against the neoliberal trust towards market-led mechanisms. From this point of view, co-production is frequently advocated as a valuable alternative to the private or public-owned service provision ([McMillan et al., 2014](#)) being conceived as a synergistic solution between state and society ([Ostrom, 1996](#)). Nonetheless, research shows that co-production can enhance precariousness and vulnerability when applied in the context of weak public institutions ([Moretto et al., 2018](#); [Faldi et al., 2019](#)), resulting in a contested and ambiguous concept ([McMillan et al., 2014](#)).

This paper enters this debate to contribute to the necessary search of alternative scales for water supply provision which can combine the adaptability and inclusivity of micro-scale (e.g., condominium rainwater reservoirs) with the wideness and controllability of the macro-scale (e.g., pipe networks). Results show risks associated with hybrid (or co-produced) systems even though acknowledging potentials of decentralized micro-scale water services. They describe the coexistence between an intermittent and scarce public-owned service with manifold grassroots initiatives – individual or collective – to meet water needs. This hybrid system supports the [Ahlers et al. \(2014\)](#) conception, being characterized by unfulfilled formal responsibilities, precarious service quality and vulnerable users, and being metaphorically a spotted zebra. Conclusions stress the importance to think beyond the mainstream approaches but within an institutionalized public framework, prioritizing justice and quality in water provision. In particular, the research maintains the necessity of an overarching public governmental framework and sheds light on the nexus among political participation, civic education and socio-technical transitions in WSS. It is shaped as an exploratory and inductive case study based on a municipality in the RJMR, in Brazil’s south-east.

The paper is organized as follows: the first section outlines the debate on water supply service and co-production; the second section describes the methodological framework; the third section illustrates in the case study in detail; the fourth section presents findings; finally, the fifth section discusses them, drawing conclusions and providing insights for further research.

Water supply systems: mainstream models and emerging issues

In most large cities water and sanitation services are based on a mixture of the three aforementioned models, consisting of a state-owned infrastructure operated and managed with the engagement of market and/or civil society actors. These systems have the following structural characteristics: a metropolitan centralized infrastructure organized in supra-municipal macro-systems; large water units for water collection, production and treatment; a defined standard of water quality; and, in most of the cases, a single operator. Moreover, they have the following operational characteristics: a network infrastructure with a high degree of centralization and poor adaptability; the same water quality standard for different water uses (e.g., drinking, washing, sanitation or industrial production); demand-driven financing approaches, which are mainly based on the consumed volume. Finally, most public utilities operating within this

framework do not involve the citizen-user in decisions about the management, allocation and pattern of water usage. These socio-technical characteristics have been defined in the past and restrict their adaptation to current challenges, such as extending the water supply service to new frontiers of cities and preventing the climate change effects (Guy *et al.*, 2010).

Micro-scale systems take advantage of local water sources through in-house or community-based simple artefacts, such as shallow wells, collective wells and rainwater harvesting. They often have strong roots in the local culture and can be arranged in complementary scales to macro-systems (e.g., neighbourhoods, courts, condominiums). On the other hand, the formal dissemination of these solutions confronts several challenges, for instance, its maintenance and operation. These informal practices, ‘outside networks’, or ‘unorthodox’ service delivery (Faldi *et al.*, 2019) are sometimes considered as unacceptable (Ahlers *et al.*, 2014), while other times as providential (Joshi & Moore, 2004).

Co-production is a ubiquitous pattern of urban growth in the Global South, where the *modern urban infrastructure* had not reached the universalization of WSS. Co-production (Ahlers *et al.*, 2014; Moretto *et al.*, 2018), ‘institutionalized’ co-production (Moretto, 2010; McMillan *et al.*, 2014), coexistence (Furlong, 2010) or hybridization of the infrastructure (Moretto *et al.*, 2018) are described in the literature as the grassroots strategies, in some cases allied to the public power, to supply marginalized areas and/or peripheries. In some cases, they encompass real cooperation between public operators and communities (Moretto, 2010; McMillan *et al.*, 2014); in others, the inefficiency of the public service is exploited by criminal groups (Graham *et al.*, 2016).

Experiences of small systems operated by communities are described for some cities in Bolivia, e.g., the widely explored case of Cochabamba (Moretto *et al.*, 2018). Despite their importance in complementing the centralized public system of water supply, the lack of institutionalization has incurred problems of environmental sustainability and community engagement. A different approach was applied by the central government for the periphery of Caracas (Venezuela). Here, institutionally recognized community organizations, *Mesas Técnicas de Agua (MTAs)*, are responsible for the activities of planning, management and even the establishment of networks, boosting participation and enhancing water access in the periphery (McMillan *et al.*, 2014). In this case, informal practices were valued as a starting point for building more adequate systems in the Venezuelan case (Moretto, 2010).

In the Brazilian metropolitan peripheries, irregular agglomeration and informal and precarious settlements represent the standard path of urban development, presenting similarities with the periphery of Caracas (Moretto, 2010; McMillan *et al.*, 2014). In the context of the metropolitan periphery of Rio de Janeiro, especially in the sub-region of the so-called *Baixada Fluminense* where our study is located, even formal settlements suffer from the precariousness of WSS. In informal settlements, the indigent population search for alternative solutions to water supply (e.g., individual or collective wells; collective taps that drain spring water; illegal connections to the public supply network). Some scholars call this entanglement of the formal and informal systems co-production, where one leans on the other without actual collaboration. Notwithstanding, there are other ways to connect the micro- and macro-scales formally organizing the co-production. For instance, Coutard & Rutherford (2013) stress that in the European context, activists, experts and policymakers at all levels are increasingly conceiving decentralized technologies as a promising way to build sustainable cities.

There is no evidence that small-scale technologies would be more sustainable than the traditional centralized infrastructure. Dissonant findings from scholars studying different world regions suggest that there is no single optimal scale for public service provision. Alternatives to formal networks are found in the peripheries of cities in northern Europe, where the formal infrastructure has not yet

been implemented. Common reasons are the low population density, the cost–benefit relationship and the technical difficulties for building cable and plumbing networks. This is especially true for wastewater. For example, several municipalities in the periphery of greater Stockholm make a clear distinction in their planning strategies by distinguishing three zones: those that are already connected to the municipal or inter-municipal water system and sewage; those that are planned to be connected in the medium and long term; and those that are definitely ‘beyond’ the municipal systems for a set of technical, geographical and economic reasons. These latter areas are still a major part of the Stockholm urban archipelago region but rely on individual wells and septic tankers (Coutard & Rutherford, 2013). This approach implies the permanent exclusion of the low-density areas from centralized networks. In this sense, it reverses the dominant trend of network expansion.

Methodology

The research is designed from a methodological standpoint as a case study. We adopted a general inductive approach and defined a course of action with the following steps in accordance with Thomas (2006):

- (A) definition of the territorial context
- (B) identification of key informants
- (C) selection of grassroots water access points (i.e., natural springs)
- (D) conduction of a survey with natural spring users
- (E) conduction of semi-structured interviews.

We explored the selected territory along a one-year-long field research. The preliminary framework of the territorial context immediately revealed the scarcity of information in relation to the informal mechanisms of water provision in *Queimados*. Consequently, it became necessary to identify key informants. The choice of informants was based on some of the main characteristics of the ‘ideal’ informant, according to Tremblay (1982): (i) a developed role in the local community; (ii) knowledge pertaining to the research subject; (iii) availability in collaborating with the research; (iv) ability to communicate his/her knowledge impartiality. Accordingly, our three key informants were: a biologist, public officer of the water quality monitoring sector of the National Foundation for Public Health (FUNASA); an environmental technician, Director of Environmental Licensing in the *Queimados* Municipal Department of Environment; a geologist, Director of the *Guandu* River Basin Committee and Professor of Geosciences.

The following step was to select the grassroots water points for a deeper investigation among those still active and used by citizens for their water needs. We selected two natural springs from two different *Queimados* neighbourhoods: *Jardim da Fonte* (*JdF*), a more urbanized district closer to the city centre, and *Villa do Rosário* (*VdR*), a peripheral and peri-urban one. We chose these two areas as they are representatives of the two *Queimado*’s water supply systems, the public network and the grassroots systems based on water springs. While *JdF* is a more formal neighbourhood served by both the public water network and a couple of water springs, *VdR* is in the bordering area of the municipality, with no water supply network and only one rudimentary access point arranged by the local residents. We relied on the STS and co-production literature to design the field-research and analyse our empirical materials. Faldi et al. (2019) suggest a three-dimensional conceptual framework that captures the main assets of hybrid systems: *actors* (stakeholders and institutions), *flows* (interactions and socio-technical relations) and *areas* (local space, including natural resources and the built environment) (p. 890). According to this overarching study,

institutional aspects, such as the distribution of responsibilities, as well as physical and socio-spatial elements, such as the distance between the users and the water sources and the user density, strongly affect an ‘unorthodox form of service delivery’ (p. 905). Drawing upon these critical assets (Faldi et al., 2019) we organized our search into two main investigative levels. As a first level, we explored the *area* through an in-field survey, focusing on users and resource. As a second level, through in-depth interviews, we explored *actors*, namely, the main involved stakeholder categories, and *flow*, namely, their relations.

Based on a non-probabilistic sample of 90 respondents² of grassroots source users, the field research made possible the portrayal of the grassroots system for water supply in *Queimados*.

We chose a non-probabilistic sample, given the impossibility of defining the exact universe of the population constituting the springs’ users. As a matter of fact, the *JdF* spring was regularly used by citizens coming by car from other municipalities. On the other hand, the *VdR* spring is located in a periurban area which escapes from standard census demographic databases. A questionnaire was conducted during three days distributed along two weeks, between the months of January and February 2014. These are summer months when the springs are intensively used. A 2018 in-field research, which is a follow-up of this exploratory study, confirmed this overall 2014 scenario (Faria, 2018).

The survey was based on nine questions related to the following variables:

- number of inhabitants per dwelling
- frequency of water collection
- type of use for the natural spring water
- access to other sources of water (e.g., connection to the public network)
- perceived quality of collected water.

Questionnaire length and content were tested through preliminary field visits, briefed internally among peers, and elaborated after an in-depth documental investigation on the water socio-technical system (see the next section). Therefore, questions were defined on the basis of theory and on empirical collected materials. The survey aims at fulfilling the first level of investigation (step ‘A’) by exploring the *area* in terms of resources and needs (Moretto et al., 2018; Faldi et al., 2019). Hence, we collected the most relevant information about the usage of the water grassroots sources, users’ characteristics and their water needs. The data collected were tabulated and analysed using multiple correspondence analysis (MCA) (Greenacre, 2010), a factoring technique that allows analysing mixed sampled data with both qualitative and quantitative variables.

Finally, nine in-depth semi-structured interviews were conducted with key respondents, that is, our three key informants plus six selected interviewees. Of these last six, three were local public institution members, one being the Commercial Director of the CEDAE Water State Company, and two being technicians of CEDAE local departments. The CEDAE technicians were interviewed together. The other three were local dwellers’ representatives: the leader of the Neighbourhood Association of *JdF*; the first vice-mayor of *Queimados* who was very active in the municipality political life in the past; and a *JdF* resident who took care of the spring.

All these different sources of data were finally combined through a triangulation approach for the analysis (Mathison, 1988).

² The sample size was purposive and not-probabilistic consistent with the exploratory nature of the study.

The case study: large network vs informal solutions in the RJMR

The municipality of *Queimados* is one of the smallest towns in the RJMR, with a population of 137,962 inhabitants and a surface area of 76,921 km². It is located in the sub-region of the so-called *Baixada Fluminense*. We selected it as a case study for its relevancy and originality. The case is, indeed, at the same time, underexplored and relevant in terms of hybrid socio-technical system for water supply since citizens widely rely on grassroots solutions. Moreover, it epitomizes a marginalized area in the Global South where paradoxically the public infrastructure draws water from unserved peripheries to supply the metropolitan centre. Moreover, the multiple and informal use of the municipality's abundant natural water sources was not documented in the scientific literature and only briefly in local documents and publications.

The formal system of RJMR: large public network for water supply

The *Baixada Fluminense* is the area of RJMR that surrounds Rio de Janeiro City, being located between Guanabara Bay and the mountains of the so-called *Serra do Mar*. Municipalities located in this sub-region, as *Queimados*, are formally supplied through a large network for water provision based on three connected hydrological reservoirs, forming the Guandu/Lajes/Acari system (INEA, 2013). This network is operated by the State of Rio de Janeiro Water and Sewage Company (CEDAE)³. This system divides municipalities into two river basin districts (see Figure 1). These districts correspond respectively with the *Guandu* River Basin and the *Guanabara Bay* River Basin. This hydrological system supplies a population of 9,657,570 people with a current demand of approximately 50 m³/s (INEA, 2013).

The Acari reservoir is also known as 'black lines' because of its pipes that are made of melted iron, differently from modern water supply systems. This is the smallest reservoir with a total flow of 2.63 m³/s and supplies the areas of *Baixada Fluminense*, including part of the municipality of *Queimados*. The *Lajes* reservoir brings water through two pipelines that conjoin the Guandu System. It provides water to different municipalities, including *Queimados* that receives 0.2 m³/s and uses this water to supply its Industrial District. Finally, the *Guandu* reservoir is by far the largest with a current production capacity of nearly 43 m³/s.

Nearly half of treated water from the *Guandu* reservoir supplies the southern zone of the Rio de Janeiro Municipality (the region's wealthiest area). The other half is divided between the city's north zone and the *Baixada Fluminense* region, through the so-called *Marapicu* reservoir with five pipelines. Two of these pipelines supply the *Baixada Fluminense*: (i) the main *Baixada Fluminense* pipeline (ABPF) and (ii) the new *Baixada Fluminense* pipeline (NABF), carrying water to the region at 9 m³/s (INEA, 2013).

Through resources from the PAC (*Plano de Aceleração do Crescimento*)⁴, the conclusion of the NABF made it possible for the water from the *Guandu* reservoir to arrive in the municipality of *Queimados*. Nonetheless, even after having concluded the *Baixada's* second pipeline, the company

³ In Brazil, municipalities are legally responsible for sanitation services. However, they can delegate the provision of these services to state, municipal or private concessionaires, while remaining responsible for management, planning and regulation.

⁴ PAC (Growth Development Program) is a strategic plan of investments formulated by the Federal Government in 2007. It promoted the resumption of the planning and execution of the country's large-scale projects in social, urban, logistical and energy infrastructure.

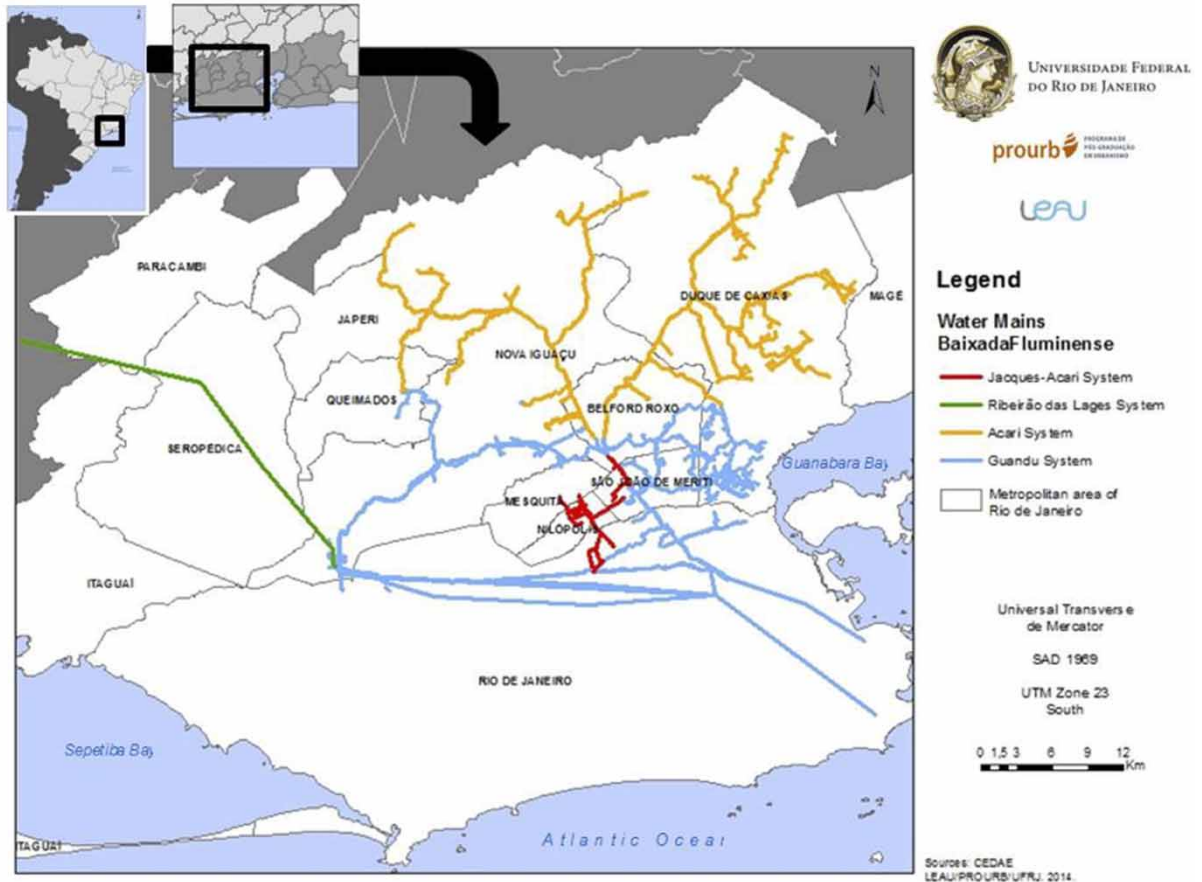


Fig. 1. Water supply system – western part of greater Rio de Janeiro. Source: created by LEAU with data from the CEDAE.

recognizes that it is still far from providing the municipality with a satisfactory water supply service since the flux of water is discontinuous.

The construction of four reservoirs that will serve the municipality has been planned: *Queimados I*, *Queimados II*, *Camburi* and *Vitória*. In 2018, the *Queimados I* and *Camburi* reservoirs were opened, improving the water supply in the served neighbourhoods. However, the *Vila do Rosário* area, on the outskirts of the municipality, remains without water supply.

Informal water supply system in Queimados

Citizens in *Queimados* developed across the span of the last 50 years a practice consisting of collecting water at one of several natural local springs. *Queimados* residents, living in the neighbourhood with no public water service provision, have developed different grassroots strategies to access water: individual actions; organized in small informal groups; or, sometimes, in neighbourhood associations. Where the connection with the CEDAE network exists, residents combine it with the use of shallow wells dug by residents, the less common artesian (or semi-artesian) wells, and the collective use of

water springs. The collective use of springs in *Queimados* is the expression of a spontaneous community initiative and of local cultural values. On the other hand, it represents a solution that lacks any technical control and formal organization whatsoever. Citizens of *Queimados* and from neighbourhood municipalities fetch water from the *Queimados*' springs by rudimentary artefacts. A study ordered by the *Guandu* Committee, the river basin governance body, showed that some of these springs possess protective covers or buried storage spaces. In general, taps are rudimentary, installed to allow water to emerge from the ground, but without any mechanism to stop the continuous flow. The most frequently used springs have concrete structures that serve as much for their own protection as for that of their users. Users can, at times, queue for more than an hour in the summer when collecting water.

The engagement of community users has allowed some water springs to survive throughout time and to become a permanent water supply alternative. Through very basic techniques the residents from these areas have succeeded in guaranteeing a supply of water while simultaneously transforming these locations into microcosms of socialization. However, the management of these sources has been relegated to the volunteer initiative of individuals or groups of spring users. This phenomenon was actually ignored by the municipal government and its participatory bodies (so-called 'Councils'), the CEDAE and the Rio de Janeiro State government. While the springs' water was judged as being 'pure' and 'exceptional', these natural sources are increasingly subject to multiple impacts of uncoordinated human actions. This is due to the growing residential occupation in *Queimados*, the consequent increase of demographic pressure, especially in terms of water demand, and the generalized lack of appropriate solid waste management. Gonçalves & Oliveira (2010) identified and mapped a total of 21 springs in *Queimados*, most of which are currently in use. In 2018, another ten springs in the municipality were identified, for a total of 31 natural water springs (Faria, 2018).

Findings

Area: Resource, users and uses of water spring. The survey and the MCA

The municipality experiences countless problems with respect to the formal water supply. Such problems include the insufficiency and intermittency of the public supply network, frequent shortages of water and problems with water quality. Users' samples had the following characteristics: 67% of respondents were men, in contrast with the main literature on developing countries that point to fetching water being generally a female task; 55% were dwellers of houses connected to the public infrastructure; 98% were frequent users, meaning that they use the source regularly throughout the year; 20% collects water on a daily basis; 70% collects water weekly, while the remaining part monthly or just occasionally.

Survey data were analysed through the MCA method. The variables, associated with two or more values (meaning possible responses), were renamed with abbreviated identifiers. They are listed in Table 1. Figure 2 presents variables and modes used for the analysis.

The information in brackets at the top of Figure 2 shows that the analysis succeeded in explaining up to 75% of the data's variability. This is a high percentage for an MCA which expresses the association among variables and, thus, between variables and responses. The first factor (F1) is much more explicative than the second (F2), as F1 explains 70.64% of the data's variation while F2 explains only 5.05%. F1 divides the left and right planes while F2 divides the variables between the upper and lower planes. Observing the most relevant articulation between the variables composing F1, one may note a clear

Table 1. Variables and modes used in the multiple correspondence analysis, variable modalities and corresponding abbreviated identifiers. The labels are in brackets.

Variables	Descriptions and [labels]					
Location	Vila do Rosário = [Local-VdR]		Jardim da Fonte = [Local-Jdf]			
Inhabitants per dwelling	Between 0 and 4 people = PESSOAS [0–4]	Between 5 and 6 people = PESSOAS [5–6]	Between 7 and 8 = PESSOAS [7–8]	More than 8 people = PESSOAS [>8]		
Type of use of the spring water	Drink and cook = [Uso-B&C]	Drink = [Uso-Beber]	Other domestic activities = [Uso-Outros]	For everything = [Uso-Tudo]		
Collection frequency	Nearly every day = [Freq QTD]	1 to 2 times per day = [Freq-1/2XDIA]	3 to 4 times per day = [Freq-3/4XDIA]	1 to 2 times per week = [Freq-1/2XSEM]	3 to 4 times per week = [Freq-3/4XSEM]	Once per month = [Freq-Mensal]
Perception of spring's water quality	Excellent = [Percep-EXC]	Very good = [Percep-M-B]	Good = [Percep-Boa]	Relatively good = [Percep-R-B]		
Connection with public network	Connected with the public network = [Rede-SIM]	Not connected with the public network = [Rede-NÃO]				
Artesian well	Possession of artesian or shallow wells = [Poço-SIM]	No artesian or shallow wells tenure = [Poço-NÃO]				

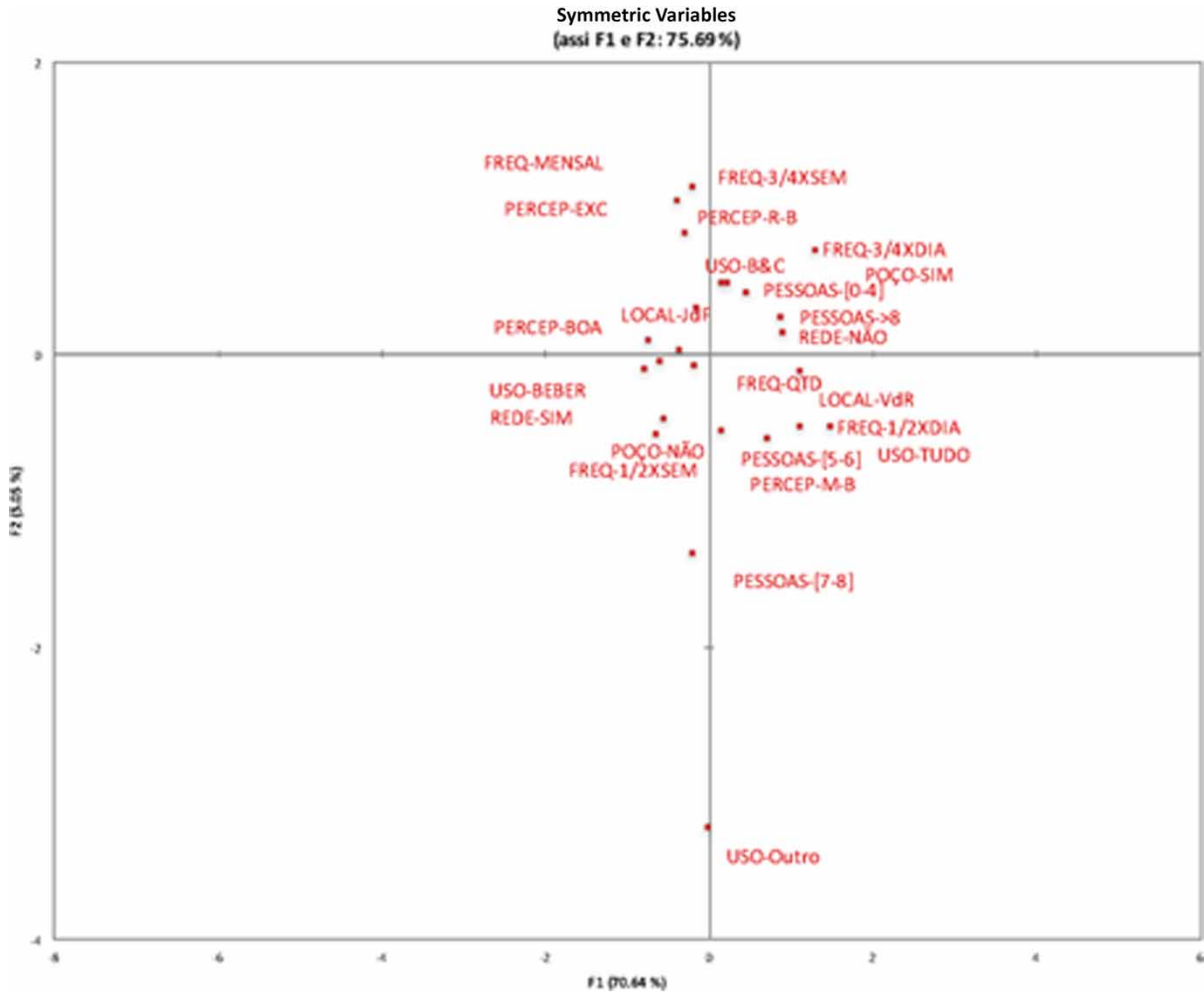


Fig. 2. Multiple correspondence analysis of survey data.

association between the following variables: *VdR* neighbourhood; daily spring water collection frequency; multiple uses of the water (variables *USO-Outro*; *USO-TUDO*); dwellings with more than eight inhabitants and no network connection (variable *REDE-NÃO*). All of these variables are located on the right side of the graph. On the contrary, *JdF* is located on the left side of the factorial plan. This left side is associated with monthly or weekly frequencies of water collection, the tendency of collecting water mainly for drinking, a high perception of the spring’s water quality, the presence of connections to the public network and the non-use of wells.

The MCA’s results show that the type of use for the spring’s water is associated with the public network’s presence or absence. In the area served by the public infrastructure (*JdF*) residents collect water from the spring mostly for drinking. On the other hand, in the other area (*VdR*), residents use spring water for all types of domestic uses, including drinking. In addition, while there is no clear association for the ‘relatively good’ perception of the spring water’s quality, that of ‘excellent’ is clearly associated

with *JdF* where there is also a tendency of comparing this water with CEDAE water. In other words, users who have access to both the public infrastructure water and the grassroots system for water supply expressed a clear preference for the grassroots system in terms of perceived water quality. The preference for water conceived as natural, in contrast to piped water, is consistent with other case studies in the Global South (Furlong, 2010), while residents of *VdR* with no access to supplied water are compelled to use spring water for everything, from drinking to domestic needs.

Actors and flows in an hybrid water supply system. The semi-structured interviews

Nine semi-structured interviews followed an open interview protocol structured on four macro-questions, each articulated in at least three and no more than five specific questions, for a total of 21 open questions. The topics of the macro-questions are listed below. They were addressed by the goals of the DESAFIO project and inspired by the specific issues that emerged in the first phase of our case study:

1. formal water service system in *Queimados*
2. informal water service system and people vulnerability
3. local government role and citizens' actions
4. outlook of future changes and opportunities for innovation.

As a first step, we transcribed the interviews, converting recorded data into textual data. Subsequently, following Thomas's analytical approach (2006), the data were organized into 12 analytical categories. The categories were identified based on the relevant aspects of the case of *Queimados*. Therefore, we implemented a codification process, categorizing the raw textual data through a progressive 'filtration'. After having identified the analytical categories, a primary selection of the textual information was performed.

Triangulation

We based our triangulation process on three pillars: (a) theoretical premises and empirical goals of our research project; (b) survey data findings; (c) recurring elements arising from the interview transcriptions. Through induction, we moved from particular data to more generalizable conclusions linked to the research problems. This process allowed us to identify the following analytical dimensions:

1. Socio-cultural
2. Health and vulnerability
3. Politico-institutional
4. Technical-infrastructurel.

For each of the above analytical dimensions, we found barriers and drivers in the aim to recognize potential for changing the current co-produced, hybrid and vulnerable reality.

Socio-cultural dimension. Both interviews and survey data showed that cultural factors are crucial in the use of springs as primary sources of water supply. Public officers working in the municipal government stressed this aspect in the interviews when they highlighted the users' preference for this water in

comparison with water from the public network. This opinion is confirmed by the survey data, which show that 100% of the sample attributes high quality to the spring water, although, the real quality of this water has not been confirmed through a formal monitoring process. Through our fieldwork, we noticed weak activism among the local community in terms of the number of associations and social organizations. In the interview with an active citizen, which was one of the oldest local leaders and a former local administrator, he evidenced the relevance of the *Queimados* community's mobilization during the period of separation from the municipality of *Nova Iguaçu* (the fourth-largest municipality in the RJMR and the second in the *Baixada Fluminense*) in the early 1990s. However, we identified only one small local citizen association throughout the fieldwork.

In addition, different attitudes stood out among the residents interviewed with respect to the precariousness of WSS in the municipality.

Some houses were equipped with both a connection to the CEDAE's network and private wells. In these cases, dwellers also collect water from the spring and some interviewees were satisfied with the hybrid service. Some others decried the non-universalization of public services despite receiving it. Others not receiving any service expressed their profound personal discomfort and distrust in public institutions. All field materials, even from different sources, showed the dissatisfaction of residents living in districts without water distribution networks and waste collection. With relation to these areas, survey respondents and interviewees expressed disbelief in the improvement of the informal system with respect to the universalization of services.

Within this scenario, it was possible also to meet active residents who are engaged in the implementation of alternative solutions to the lack of an effective public service. An example is a joint effort to install pipes for the creation of a sewage network for a neighbourhood school. On the other hand, residents interviewed through questionnaires or semi-structured interviews cited years of clientelist politics by stating that they had lost hope not only in the public authorities' initiative but in any possible dialogue with them. This political culture is rooted in a specific socio-political context that ultimately nourishes the public's behaviours and convictions. Interviewees cited patronage dynamics. For example, a candidate for mayor paid for the spring's concrete structure in *Jardim da Fonte* and other interviewees reported similar stories about the tendency to build stretches of the network in the peripheral neighbourhoods only during the election period.

The use of springs and wells is first and foremost a solution collectively implemented by individuals rather than the product of a community initiative (Seyfang & Haxeltine, 2012). However, the spring in *JdF* revealed a particularly interesting aspect. Indeed, at the time of the research, this spring, that is currently dried up (Faria, 2018), was a place of gathering and of socialization. It triggered the emergence of an informal user community, that has identified one of the users and neighbourhood resident as a caretaker for this common space, something that resembles an informal and spontaneous version of the 'well keeper' in Kinshasa described by Moretto et al. (2018). This dynamic has not been reinforced enough to preserve the spring's integrity. On the basis of these pieces of evidence, we identified as socio-cultural barriers to integration the lack of local social mobilization and the clientelism and patronage featuring local political life. On the other hand, we acknowledged as socio-cultural drivers the attitude of some individual resident to take care of the springs as well as the resident dissatisfaction for the water supply system, which might stimulate social reaction and mobilization for change.

Health and vulnerability. Informal conversations and data provided by *Queimados*'s Department of Water Quality demonstrate that there is no guarantee of the investigated springs' water falling within

standards for potable water; there were even times at which their water was judged as being unclean. This is the case of the spring in *Jdf*. While it attracts a large public, even including individuals coming from other municipalities, its water revealed the presence of *Escherichia coli* in a study performed in November 2013. Moreover, the fact that *Jdf* dried up before the end of the field research in 2014, is another expression of environmental vulnerability. Collected in different phases and manners across the research months, all of these factors clearly show that the grassroots alternatives implemented informally by local residents represent a source of public health risks, defining a context of socio-environmental vulnerability. One of our informants, a public officer of the municipal service for the Monitoring of Water Quality (a local department of the National Health Foundation), highlighted in an interview that springs are occasionally monitored but that this monitoring process is not a mandatory task of the department. The director of the *Guandu* Committee reported in his testimony that it is the responsibility of the municipal government to monitor the springs' water quality and that the Committee also encourages voluntary monitoring initiatives in the entire river basin's area (*Guandu* Basin). Our findings show these initiatives are not institutionalized and, in some cases, water quality tests are only done upon the request of residents. The survey data show that the absence and precariousness of the formal water supply system stimulate the adoption of multiple uses of the springs.

Lacking other supply sources, the spring becomes a place where one can collect water for nourishment, personal hygiene and any other domestic use. These springs are neglected by the public authorities despite the fact that they are numerous in *Queimados* (Faria, 2018) and that they provide a service to a substantial amount of people. As for environmental vulnerability, the lack of knowledge on local water heritage and the lack of public institution committed to protecting it leads to uncontrolled overexploitation of local water sources. In both of the studied districts, there was neither waste collection and treatment, nor monitoring of the destination of waste coming from residences surrounding the springs. The lack of an institutionalized monitoring process of water quality and the lack of accountability of public government at both the municipal and state scales represent the main barriers for change. As long as there is a lack of transparent and official distribution of power and duties among the several institutions involved, none of the institutions will be really accountable for WSS inefficiency and, consequently, for public health problems. On the other hand, public health risks constitute a driver for a change of the current hybrid situation. Actually, the precarious access to safe water of a large part of the *Queimados*' population (more than 40% according to our public officer informant) may be a trigger for future mobilization and change of the current system.

Politico-institutional. In the 1990s, *Queimados* was excluded as a municipality from other investment programmes promoted by the state government to broaden the access to WSS services in the *Baixada Fluminense*. The interview data highlight that this dynamic persists partially even today. On the one hand, the construction of a new reservoir, the *Guandu II*, encourages expectations as it will benefit *Queimados*. On the other hand, the interviewees from public institutions admit that this infrastructure will not be implemented within the short term and believe that the additional water that the municipality will receive will not allow for the water distribution network to be expanded. Such uncertainty related to the public infrastructure has stimulated the emergence of the grassroots systems in the absence of a universal water supply service, which made residents become spring users. However, they never constituted a single and integrated community capable of acting as an organized entity and cooperating with other institutional levels. It is difficult to conclude here if this dynamic of exclusion is part of a broader strategic design steered by political and governmental entities; if these entities ultimately got used to the

existence of the informal system and incorporated it into a hybrid system (Ahlers *et al.*, 2014); or if both systems, formal and informal, ended up reciprocally co-producing and becoming a permanent solution as a pair (Joshi & Moore, 2004). Certainly, the case of *Queimados* does not fit the kind of fortunate co-production illustrated elsewhere (Ostrom, 1996; Moretto *et al.*, 2018; Faldi *et al.*, 2019).

The director of the *Guandu* Committee stated that an alternative form of WSS management for these municipalities would be creating inter-municipal consortia. However, he pointed out that the heavy bureaucracy and local government's inaction (state and municipal governments) hinders the development of this model of governance. Ostrom *et al.* (1999) stressed that in the management of common-pool resources, the institutional pluralism, or diversity (i.e., the distribution of power and responsibilities among more than one institution), is just as important as the biological diversity of ecosystems. WSS management in the RJMR, and even more generally in all of Brazil, is resistant to such diversity. It reproduces models with structures from different historical contexts that do not appropriately respond to current needs (Britto *et al.*, 2018). The political-institutional context seems marked by the priority CEDAE gives to the municipality of Rio de Janeiro, to the detriment of fringe areas; moreover, the municipal government, who are responsible, on a legal basis, for the municipality's environmental quality and the protection of public health and WSS management. Therefore, the organizational inertia and resistance to institutional diversity constitute the main barriers to change. On the other hand, the similarity of water supply conditions among neighbouring municipalities can work as a leverage to promote consortium or other inter-municipal models, operated at an intermediate-scale.

Technical-infrastructural dimension. From a technical-infrastructural standpoint, a macro-system supply paradigm prevails in the investigated territory: the network has the central infrastructure and it is organized on a metropolitan scale in the supra-municipal macro-systems; water is centrally produced in large extraction and treatment centres, and there is one sole operator. The CEDAE, as the only operator, takes decisions regarding this model in a centralized fashion. By delegating the provision of services to the CEDAE in a 30-year contract, *Queimados* is simultaneously delegating decisions pertaining to WSS management in its territory. This macro-system's infrastructure is especially present in the central areas of *Queimados*. Our interviewee, the Director of *Guandu* Basin Committee, observed that the *Guandu* system, which is supplied by the transfer of the Paraíba do Sul River's waters, will be less and less capable of supplying RJMR's population of 12,090,607 people (and rising). In this scenario, the integration of the large public-owned infrastructure with the micro-scale of grassroots solutions can represent an opportunity to reinvent and redesign the water supply system in the light of the principles of democratization and hydrosocial cycle balance (Moretto, 2010; McMillan *et al.*, 2014; Swyngedouw, 2015). The research shows that the cultural dominance of a large, centralized infrastructure model and the strong political interest and power structure associated with this system are the main barriers to promote change. On the other hand, the increasing water shortage and incapacity of the large infrastructure to face frequent droughts can work as drivers of changes.

Conclusions

Our research started with the need to find alternative scales of water supply service, in order to face the increasing challenges associated with water provision, especially in the Global South. By entering the academic debate on hybrid systems and co-production, the paper presents results of a case study that

is part of a larger research project which explores grassroots water supply alternatives as socio-technical innovation for the democratization of WSS. The paper confronts the question of the suitability of a hybrid solution for water supply, observing hidden pros and cons behind a spotted zebra. The spotted zebra is the metaphor that we employed for unclassifiable hybrid models which are especially rooted and entangled in the Global South WSS (Bakker *et al.*, 2008; Moretto, 2010; McMillan *et al.*, 2014; Moretto *et al.*, 2018). Our findings suggest that, in the RJMR, the missing resources are effective public governance and a structured institutional framework for an integrated and trans-scalar water policy solution. These two factors are necessary conditions for any sustainable transition, to combine a responsible government at a macro-scale with an active and aware community at the micro-scale within a single institutional framework. For this reason, it is important to also take into account variables other than recovery costs, revenue cap and price cap. In a context where the inefficiency of the centralized model, based on a large and complex public infrastructure, forms a hybrid and uncontrolled system via grassroots informal actions, both formal public system and the informal system failed. As a matter of fact, these two systems working at the same time, but separately, produced a condition of vulnerability for the local population and environment. On the one hand, the weak access to public services made residents arrange alternative paths to provide their basic needs. On the other hand, local residents operating mostly individually and with no necessary technical information to exploit a common good, may have contributed to damage part of the numerous natural springs (since some are now dried), through several years of uncontrolled use.

We identified four critical dimensions: socio-cultural, political-institutional, health and vulnerability, and technical-infrastructural. They allowed us to choose a specific interpretative perspective to analyse our vast empirical materials. Findings emphasize the local political culture as the main barrier to change. We agree with the importance of inscribing water supply service within the public service realm and we do not support any position of rejection of the state water provision. Without an organized and effective, even though conflicting and complex (Furlong, 2010), institutional framework, the process of co-production results in a fragmented, unequal and unsafe hybrid system. Grassroots or informal solutions cannot offer on their own an alternative path to the large public network for the democratization of water supply services. However, within a structured, institutional, public system, which assures clear rules and responsibilities, they could offer a valuable integrative option for the improvement of the water supply system, as was pointed out by some of the interviewees and stated in previous studies (Moretto, 2010; McMillan *et al.*, 2014). The Venezuelan case of *MTAs* in Antimáno (McMillan *et al.*, 2014) and the Colombian case of *JACs* in Quibdó (Furlong, 2010) support this consideration.

In terms of empirical findings, the case of *Queimados* is consistent with others in the Global South analysed through the lens of co-production (Furlong, 2010; McMillan *et al.*, 2014; Moretto *et al.*, 2018). Nonetheless, differently from previous works, our conclusions warn against the idea to identify hybrid systems as a satisfactory alternative or to label co-production as a collaborative/participatory approach for water service provision. Rather, in the analysis of STS, we stress the importance of the *politicization* of grassroots participation. With *politicization* we entail an involvement that underpins a political vision, that is addressed by clear values and ethics and that is aimed at a common and public project. Separate grassroots initiatives, which are mobilized to compensate the lack of infrastructure, result in fragmentation (Bakker *et al.*, 2008) and (co-)produce vulnerable ‘spotted zebras’ that should not be considered the normality (Furlong, 2010). Grassroots actions that meet public institutions commitment and willingness to improve the public service can result in a long-term political project. From this point of view, a co-design process should come before the co-production. To address any socio-technical transitions

towards justice, the political engagement is as important as the existence of other social, natural and financial resources. *Politicization* is also as fundamental as other conceptual dimensions like *area*, *flow* and *actors* (Faldi et al., 2019), even though it is usually neglected. The quality of this engagement depends on the existence and functioning of democratic arenas as a space of civic and political education, where social needs can be negotiated and discussed and solutions co-designed rather than occasionally co-produced. We contend the public sphere with its institutions and space of public debate be a pre-condition for an equal and effective water service, where co-production may work in a democratic way. From this point of view, our contribution to the debate on WSS is in terms of stimulus for renewed attention on the importance of the political character within the collaboration between grass-roots actors and public institutions. Indeed, the case of *Queimados*, shows that this politicization is what makes a difference between a passive and fragmented involvement and an inclusive construction of a social project. Participatory arenas are crucial to address transitions towards justice and democracy. Yet, we also acknowledge that participation itself is not a panacea and participatory institutions are not immune to clientelism/patronage (Furlong, 2010). For this reason, engagement practices need to be part of a political project that, assuring spaces of political participation, makes the civic and political education of the local community a constant basis for service governance. Future researches, especially, but not only, on the Global South, should expand on these neglected dimensions of STS (i.e., pedagogical, ethical, political) and, above all, explore their interconnections. Alternative scales of service provision are increasingly necessary both in the north and south to face contemporary challenges of water supply. Such a socio-technical change cannot occur without a cultural change. If spaces of political participation are conceived as spaces of education, and education as a process of political capacitation, we would have communities that are active in directing socio-technical transition towards social justice objectives. These kinds of nexus deserve further attention in water policy study.

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Data availability statement

Data cannot be made publicly available; readers should contact the corresponding author for details.

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